Collection Systems

Grade 1 – 2

Course #1213

Fleming Training Center
March 3-6, 2014

www.tn.gov/environment/water/fleming.shtml

Collection Systems Grade 1&2

Course #1213

March 3-6, 2014

<u>Monday, July 29:</u>

8:30	Wastewater Characteristics	Dennis Conger
9:30	Wastewater Collection Systems	Dennis
10:30	Flow Measurement	Dennis
12:00	LUNCH	
1:00	Collection Math Review	Dennis

<u>Tuesday, July 30:</u>

8:30	Pipe Materials and Installation	Dennis
9:30	Lift Stations	Dennis
10:30	Collection System Safety	Dennis
12:00	LUNCH	
1:00	Pipeline Cleaning and Maintenance *(Hydraulic Cleaning, Mechanical Cleaning, Chemicals, and Hydrogen Sulfide Control)*	Dennis

<u>Wednesday, July 31:</u>

8:30	Inspection and Testing *(Purpose, Manholes, CCTV, Smoke Testing, and Dye Testing)*	Dennis
10:00	Rules and Regulations	Dennis
11:30	LUNCH	
12:30	Tennessee One Call	Holly Austin
1:00	Underground Repair	Dennis
1:30	Sewer Rehabilitation	Dennis
2:00	Cross Connection Control	Dennis

<u>Thursday, August 1:</u>

8:30	Pumps	Dennis
10:00	Equipment Maintenance	Dennis
11:00	LUNCH	
12:00	Course Evaluation and Exam	Dennis

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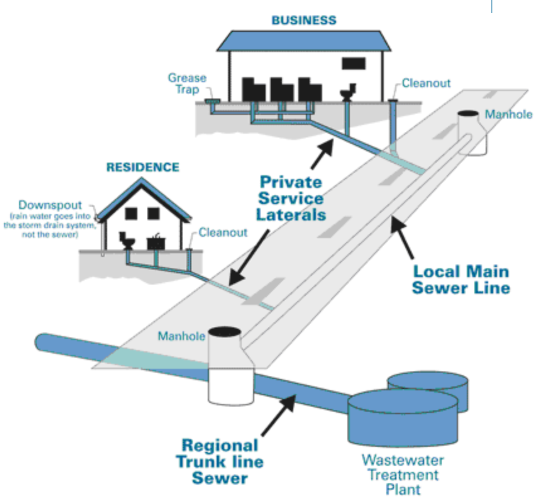

Diagram of a sanitary sewer system

State of Tennessee

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Your Partner in Clean Water

Collection Systems

Section 1

Overview

Suggested Collection System Exam References

The following are approved as reference sources for the collection examinations. Operators should use the latest edition of these reference sources to prepare for the exam.

Textbooks

California State University, Sacramento (CSUS) Foundation, Office of Water Programs (www.owp.csus.edu)
- Operation of Wastewater Treatment Plants, Volume I and II
- Operation and Maintenance of Wastewater Collection Systems, Volume I and II
- Manage for Success

Water Environment Federation (www.wef.org)
- Operation of Municipal Wastewater Treatment Plants - Manual of Practice No. 11
- Existing Sewer Evaluation and Rehabilitation - Manual of Practice FD-6
- Wastewater Collection Systems Management - Manual of Practice No. 7

Regulations

- Code of Federal Regulations, Title 40 (www.gpo.gov).
- Design Criteria for Sewage Works, State of Tennessee, Department of Health and Environment, Division of Water Pollution Control, Nashville, 1995.
- Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, TN, December 2009, Section 1200-5-3.

Study Guides

- WEF/ABC Collection Systems Operator's Guide to Preparing for the Certification Examination, Water Environment Federation, (www.wef.org).
- Applied Math for Wastewater Plant Operators, Price, Joanne. 2000. Boca Raton, FL: CRC Press (www.crcpress.com).

Suggested Primary Collection System Exam References

The following are approved as reference sources for the ABC water treatment examinations. Operators should use the latest edition of these reference sources to prepare for the exam. These reference are not the only reference an operator should use in studying for the exam, however, these are the primary references used in developing the exam.

Collection 1

- ****CSUS Operation and Maintenance of Wastewater Collection Systems Volume I**
- ****CSUS Operation of Wastewater Treatment Plants Volume II**
- ***Design Criteria for Sewage Works State of Tennessee Department of Health and Environment Division of Water Pollution Control Nashville, Latest Revision***
- **CSUS Operation and Maintenance of Wastewater Collection Systems Volume II**
- **CSUS Operation of Wastewater Treatment Plants Volume I**
- **Price Joanne Kirkpatrick Applied Math for Wastewater Plant Operators Technomic Publishing Company Inc. Lancaster PA 1991**
- *Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, Latest Revision*

Collection 2

- ****CSUS Operation and Maintenance of Wastewater Collection Systems Volume I**
- ****CSUS Operation of Wastewater Treatment Plants Volume II**
- ****CSUS Operation and Maintenance of Wastewater Collection Systems Volume II**
- **CSUS Operation of Wastewater Treatment Plants Volume I**
- ***Design Criteria for Sewage Works State of Tennessee Department of Health and Environment Division of Water Pollution Control Nashville, Latest Revision***
- **CSUS Operation and Maintenance of Wastewater Collection Systems**
- *Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, Latest Revision*

There are 2-3 primary references for each of exam. The ** denotes that 20+ of the exam items are linked to the noted reference.

Bold items have at least three items linked to them. Any references that are not in bold, have only 1-2 items linked to them.

The Tennessee State references are included, however, there is a sixth reference if the sixth had at least three items linked to it; in some cases this was a tie of 2-3 references with just a few items each. State of Tennessee references are italicized.

Grade 2 Collection Systems Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information which are important to know in order to be a successful and proficient Grade 1 Collection Systems Operator. The list may not be all inclusive, and knowledge of additional topics may be of benefit to the operator.

Category of Information: Process

Gravity Sewers
- Describe
- Operation/maintenance
- Design/Construction

Pressure Sewers
- Describe
- Operation/maintenance
- Design/Construction

Vacuum Systems
- Describe
- Operation/maintenance
- Design/Construction

Sewer Equipment
- Application
- Maintenance
- Use/Procedure

Aeration
- Purpose
- Describe types

Chemical Additives
- Purpose
- Methods
- Equipment

Chlorination
- Purpose
- Methods
- Equipment

Corrosion Control
- Describe
- Methods

Infiltration/Inflow Devices
- Describe
- Methods of inspection and testing
- Concept of sewer rehabilitation

Lift Stations
- Operation/maintenance
- Design/Construction

Flow/Velocity Measurement
- Describe
- Purpose
- Flow regulators

Manholes
- Describe
- Purpose
- Design/Construction

Cross-Connection
- Definition
- Types of devices

Category of Information: Support Systems/Equipment

Motors
- Single phase
- Poly phase
- Variable speed

Drives
- Coupled
- Direct (Shaft; Gear)
- Speed Reducer (Fixed; Variable)
- Right angle

Blowers and Compressors
- Centrifugal
- Positive displacement (Rotary; Piston)

Generators – AC & DC

Engines – Gasoline, Diesel & Gas

Hydrants (Basic)

Pumps
- Air Lift
- Centrifugal
- Positive displacement
  - Piston plunger
  - Progressive cavity
  - Diaphragm
- Screw
- Turbine
- Metering
- Ejector

Joints
- Flanged
- Compression
- Dresser
- Victualic
- Fused
- Threaded

Category of Information: Support Systems/Equipment (continued)

Valves
- Ball
- Check
- Globe
- Gate
- Plug
- Petcock
- Pressure control
- Vacuum relief
- Mud
- Butterfly
- Multiport
- Telescoping
- Sluice Gate
- Air release
- Foot
- Altitude

Pipes
- Types
- Cleaning/maintenance
- Sewer rehabilitation

Fittings
- Coupling
- Union
- Plug/Caps
- Corporation (Ferrell; Cock)
- Curb Stop
- Special

Odor Control
- Biofilters
- Chemical Additives
- Scrubbers

Rolling Stock
- Service vehicles
- Fork lifts
- Trucks
- Tractors
- Trailers
- Lawn Mowers
- Loaders
- Portable pumps
- Generators

Chemical Feeders
- Solids
- Liquids
- Slurry

Measuring and Control
- Signal generators
  - Kennison nozzle
  - Magnetic flowmeter
  - Parshall flume
  - Proportional weir
  - Rectangular weir
  - Venturi
  - Propeller meter
  - Ultrasonic
  - Pitot tube
- Signal transmitters
  - Electric
  - Pneumatic
  - Hydraulic
  - Mechanical
  - Telemetry
- Signal receivers
  - Counters
  - Indicators
  - Log Scale Indicators
  - Totalizers
  - Recorders
  - Combination recorders
- Meters
  - Hydraulic – Rotameters
  - Electrical – Amp
  - Electrical – Watt
  - Electrical – Watt Hour
  - Electrical – Multi
  - Electrical – Multi – VOM
  - Electrical – Megger
  - Mechanical – RPM
- Alarms
- Controls
  - Pneumatic
  - Float
  - Hydraulic
  - Electrical
  - Telemetry
  - Timers

Transformers
- Step down
- Step up

Safety Equipment
- Personal protection gear
- Traffic control (Warning devices; Barricades)
- Hazard detection
- First Aid/Hygiene

Category of Information: Laboratory

Materials testing
- Concrete
- Piping

Category of Information: General Information/Knowledge

Units of expression
- Define units
- Convert units

Sources and characteristics
- Characterizing sources
- Quality/quantity
- Identify characteristics
- Describe effects

Electrical
- Basic concepts
- Math calculations

Hydraulics
- Basic concepts
- Math calculations

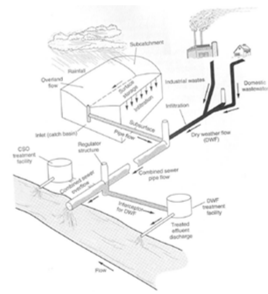
Maps/plans
- Interpretation and use
- Describe types

Wastewater Characteristics

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

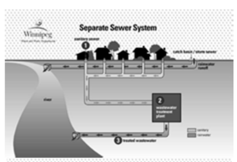
Wastewater

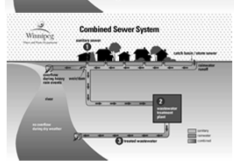
- Defined: water supply of a community or industry after it has been used
- Treatment: "onsite" or offsite ("centralized")
- Offsite treatment requires a "collection and conveyance" system



What are the Wastewater Flows?

- Sanitary Sewer:
  - Domestic and industrial waste
- Storm water:
  - snow melt, street wash, etc.
- Combined sewer:
  - sanitary plus storm
- Infiltration/inflow



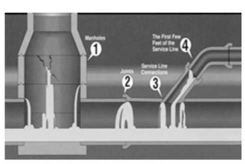


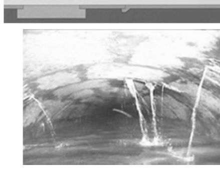
I/I

- Inflow – Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage.
  - Inflow differs from infiltration in that it is a direct discharge into a sewer rather than a leak in the sewer itself.

I/I

- Infiltration – the seepage of groundwater into a sewer system, including service connections.
  - Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.
  - Due to age and condition of system and portion of system submerged in groundwater
- Exfiltration – liquid wastes and liquid-carried wastes that unintentionally leak out of a sewer pipe system and into the environment





Wastewater flow rates

- Rule of thumb:
  - US domestic is about 100 gpd/person
  - Developing countries: 5 to 50 gpd/capita
  - Other: depends on facility (industry, commercial, etc.)
  - I/I can be significant
- Units:
  - 3.7854 liters per gallon
  - In U.S., gallons most frequent unit of volume
  - MGD = million gallons per day
  - Concentration: mg/L or lbs/MG

Wastewater flows: why do we care?

- Collection and conveyance system design
  - Are they getting shorter or longer as the years go on?
  - Getting longer and further away from the treatment plant means the water spends more time in the system, which also means water easily becomes septic.
- Treatment system design
  - Hydraulic criteria: must be able to pass peak flows
  - Treatment criteria: meeting treatment standards depends often on "hydraulic residence time"
    - e.g. MG / MGD = days = residence time
  - Growth projections (population, development)

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Factors Effecting Flow Rates

- Geographical location & socioeconomic conditions
- Type of development
- Season
- Time of Day
- Climate (rain or dry)

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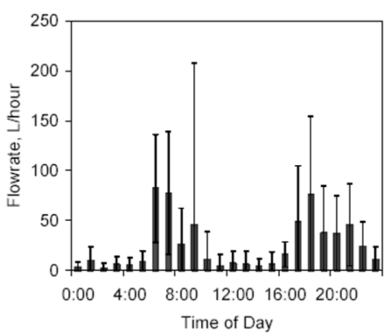
"Diurnal variations" in domestic wastewater flows



Wastewater Flows

- Flows are either normally distributed or log-normal (log of flows are normally distributed)
- Statistical procedures based on flow history used to determine average (dry weather, wet weather, annual daily), peak (instantaneous, hour), maximum (day, month), minimum (hour, day, month)

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Intro to Wastewater Treatment

Why do we treat waste?

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Prevention of Pollution

- Protection of receiving streams is main job
- Today's technology is capable of treating wastewater so that receiving streams are reasonably unaffected

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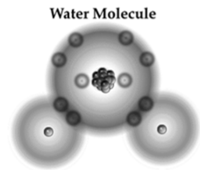
Purpose of Wastewater Treatment

- To protect public health by:
  - Removing solids
  - Stabilizing organic matter
  - Removing pathogenic organisms

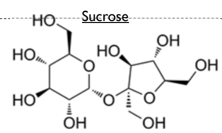
What is Pure Water?



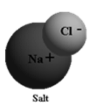
H_2O

- Water is made up of two hydrogen atoms and one oxygen atom
- "Pure" water is manufactured in labs
- Even rain and distilled water contain other substances called impurities

Types of Waste



- Organic waste
  - Contains carbon
- Inorganic waste
  - Salts
  - Metals
  - Gravel
  - Sand



- Both may come from domestic or industrial waste

Organic Waste

- Domestic wastewater contains a large amount of organic waste
- Industries also contribute some amounts of organic wastes
- Some of these organic industrial wastes come from vegetable and fruit packing, dairy processing, meat packing, tanning and processing of poultry, oil, paper and fiber.



Oxygen Depletion

- Most living creatures, including fish, need oxygen to survive
  - Most fish can survive with at least 5 mg/L DO
- When organic wastes are discharged to a receiving stream bacteria begin to feed on it, these bacteria need oxygen for this process
  - As more organic waste is added to the receiving stream, the bacteria reproduce
  - As the bacteria reproduce, they use up more oxygen, faster than it can be replenished by natural diffusion from the atmosphere
  - This can potentially cause a fish kill and odors

Oxygen Depletion

- One of the principal objectives of wastewater treatment is to prevent as much of this "oxygen-demanding" organic material as possible from entering the receiving water.
- The treatment plant actually removes the organic matter the same way a stream would in nature, but it works more efficiently by removing the wastes in secondary treatment
- The treatment plant is designed and operated to use natural organisms such as bacteria to stabilize and remove organic matter

Human Health

- Initial efforts came from preventing disease outbreaks
  - Most bacteria in wastewater are not harmful to humans
  - Humans who have a disease caused by bacteria or viruses can discharge some of these pathogens
  - Many serious outbreaks of communicable diseases have been traced back to contamination of drinking water or food from domestic wastewater
- Good personal hygiene is your best defense against infections and disease

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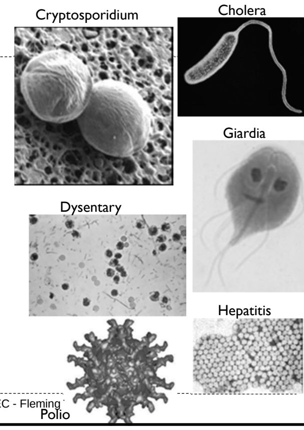
Diseases

- Bacteria
  - Cholera
  - Dysentery
  - Shigella
  - Salmonella
  - Typhoid
- Viruses
  - Polio
  - Hepatitis (Jaundice)
- Protozoa
  - Giardia lamblia
  - Cryptosporidium parvum



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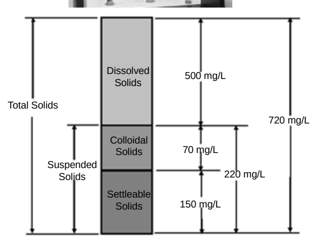
Solids

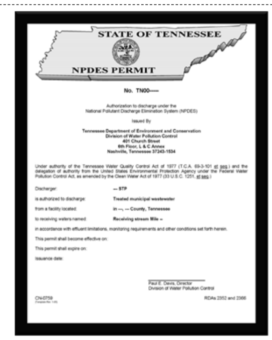
- Total solids
- Dissolved solids
- Suspended solids
  - Settleable
  - Nonsettleable
- Organic and inorganic solids
- Floatable solids



21 TDE

NPDES Permit

- National Pollutant Discharge Elimination System
  - Required by the Federal Water Pollution Act Amendments of 1972 to help keep the nation's water suitable for swimming and for fish and other wildlife
  - Regulates discharges



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Water Pollution

- Any condition caused by human activity that adversely affects the quality of stream, lake, ocean, or groundwater.

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Importance of Organic Matter

- Organic material consumes oxygen in water.
  - Bacteria will "feed" on organic matter and most need oxygen to be able to do this.
  - We want these bacteria to "feed" on the organic matter and use it up in the plant and not in our receiving water.
- High concentrations of organic material can cause taste and odor problems in recreational and drinking water.
- Some material may be hazardous.

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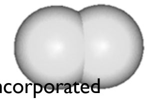
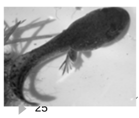
Dissolved Oxygen



- Dissolved oxygen is oxygen that has been incorporated into water.
- Many aquatic animals require it for their survival.



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Dissolved Oxygen

- There are two important factors that can influence the amount of dissolved oxygen present:
  - Water Temperature
    - Greater temperature → Less DO
    - Lower temperature → More DO
  - Organic matter
    - Organic material requires oxygen to decompose.
    - More organic material requires more DO, and will tend to deplete water of DO.

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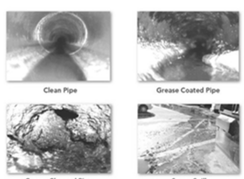
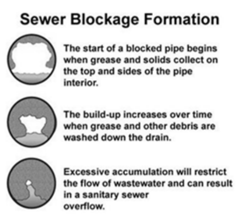
Oil and Grease

- Generally listed under one heading called FOG (fats, oils and greases) as it is often not important to know the exact make-up of this group of components.





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Solids

- Cause many problems:
  - Fill storage areas, clog ditches and channels.
  - Interfere with mechanical systems.
  - Associated with taste/color/clarity problems in drinking water.

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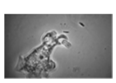
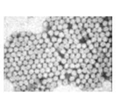
Biological Constituents

- Many are human pathogens
- Most occupy a role in the treatment process
- They are:
  - Bacteria
  - Archaea
  - Fungi/yeast
  - Protozoa
  - Rotifers
  - Algae
  - Viruses


Amoeba ingesting alga


Human hepatitis A virus


Paramecia conjugating

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Typical Wastewater Characteristics

- Fresh wastewater is usually a grey/dishwater color
  - Typically septic wastewater will have a black color
- Fresh domestic wastewater has a musty/earthy odor
  - If the wastewater is allowed to go septic, this will change significantly to a rotten egg odor associated with the production of hydrogen sulfide gas

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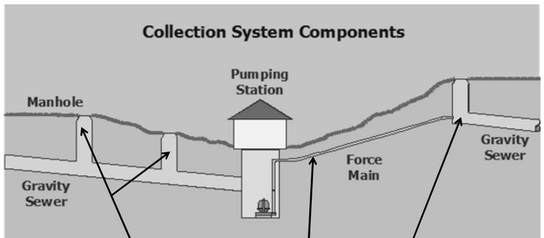
Wastewater Collection and Conveyance System



Manholes should be placed every 300-500 feet apart to provide access for inspections and cleaning

Min size is 4"

Constant minimum slope is required to provide a velocity of at least 2 fps to avoid solids depositing

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Wastewater Collection and Conveyance System

- Manholes must be installed:
  - At the ends of any line 8" in diameter or larger line
  - Changes in grade, size of pipe or alignment
  - At intersections
  - And not greater than 400 ft. on a 15" diameter and smaller sewers or 500 ft. on 18-30" sewers
- Horizontal Separation – sewers should be laid with at least 10 feet of horizontal clearance from any existing or proposed water line
- Vertical Separation – when sewers must cross a water line, they should be laid 18" below the bottom of the water line

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Wastewater Collection and Conveyance System

- Hydrogen sulfide is made in the collection system and can:
  - Make waste more difficult to treat
  - Damage concrete structures
  - Cause odor problems
- Biological activity in long, flat sewer lines will likely cause:
  - Hydrogen sulfide production
  - Oxygen deficiency in sewers, manholes or wetwells
  - Metal and concrete corrosion
- Chlorine can be used in the collection system or at the plant headworks to oxidize hydrogen sulfide

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Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment

- Screening
- Grit Removal
- Preaeration
- Flow Metering and Sampling

→ Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

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Aerated grit chamber
- 1 ft/sec flow through grit chamber
- Used to remove grit – heavy, mainly inorganic solids (sand, egg shells, gravel, seeds, etc.)
- Aeration also freshens wastewater and helps remove floatables

Mechanical bar screen with debris
- Failure to keep a bar screen clean can result in a shockload
- Removes roots, rags, cans, etc

Muffin Monster (grinder)

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Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment

- Sedimentation and Flotation

→ Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

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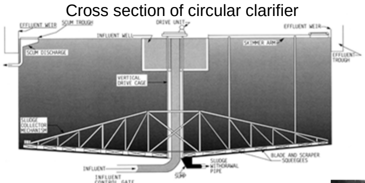
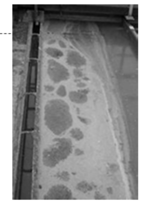
Primary Clarifier

Cross section of circular clarifier



Scum removal



- Velocity drops to < 1 fps
- Separates settleable and floatable solids
- Detention time ~ 1.5-2.0 hrs
- Raw water is gray

Rectangular clarifier

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Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment

- Biological Treatment
- Sedimentation

→ Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

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Trickling Filter

Secondary clarifier

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Fine Bubble Diffusers

Mechanical Aeration

Oxidation Ditch

SBR – Sequencing Batch Reactor

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Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment

→ Tertiary Treat. (Advanced) → Disinfection

- Chemical Phosphorous Removal
- Biological Nutrient Removal
- Multimedia Filtration

Solids Treatment

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Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment

→ Tertiary Treat. (Advanced) → Disinfection

Ultraviolet Irradiation
Chlorine Gas
Sodium Hypochlorite
Calcium Hypochlorite

Solids Treatment

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Disinfection

- Purpose is to kill pathogenic organisms still in wastewater.
- Typically wastewater must contain 200 cfu/100mL for Fecal coliforms or 126 cfu/100mL for *E. coli* to be considered "disinfected"

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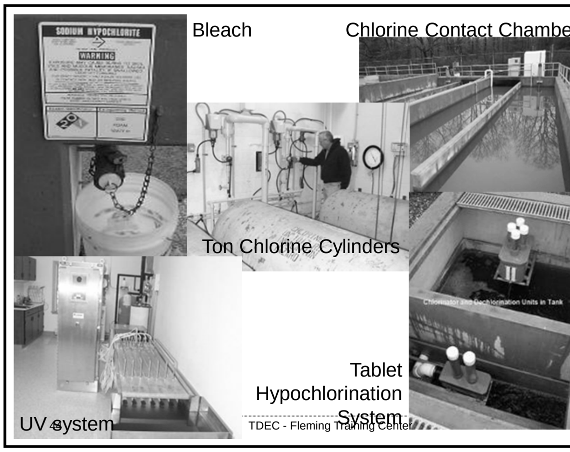

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Solids Treatment

Primary Treatment → Solids Treatment

Secondary Treatment → Solids Treatment

- Digestion
- Dewatering
- Disposal

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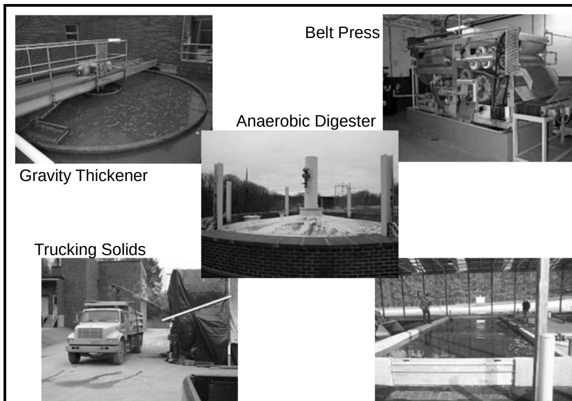

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Effluent Discharge

- Most wastewater is discharged to a receiving stream, river, lake or ocean.
- Some is reclaimed or reused on golf courses, cemeteries, parks, etc.

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Wastewater Collection Systems

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Gravity
Small Diameter Gravity Systems (SDGS)
Pressure (STEP/STEG and Grinder Pump)
Vacuum

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1

O&M of Collection Systems

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- The facilities should be kept in good operating condition
- What happens when collection systems fail due to lack of or improper operation and maintenance?
  - Blockages occurring in the sewer line that result in backups into homes, businesses and other customer facilities
  - Bypassing raw wastewater
  - Street collapse

2

Building Service Lateral

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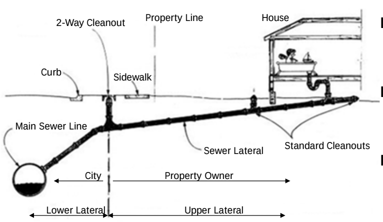

Typical dwelling served by a main sewer in the street

- Connects internal plumbing to street sewer
- Usually homeowner is responsible
- Cleanout minimum **3 ft** from foundation
- Typically **4 inch** diameter

3

Conventional Gravity Sewer

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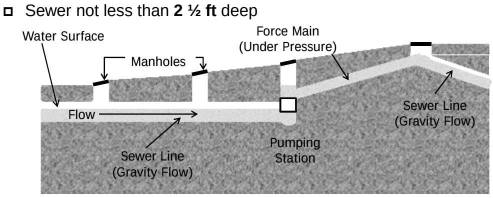
- Uses natural slope of land to flow by gravity
- Manholes every 400-500 ft
  - State requirement: manhole at distance ≤ 400 ft for sewers 15 inches or less and 500 ft for sewers 18 to 30 inches.
- Pump or lift station
- Scouring velocity- **2 ft/sec**
  - Flow < 2 ft/sec may lead to settling out of solids, stoppages, production of odors including toxic hydrogen sulfide, corrosive conditions.
- Sewer not less than **2 ½ ft** deep



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Gravity Collection Sewer

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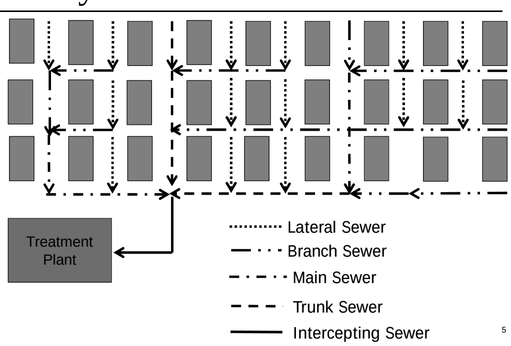

5

Gravity Collection Sewer

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- Building sewer – a gravity-flow pipeline connecting a building wastewater collection system to a lateral or branch sewer
  - The building sewer may begin at the outside of the building's foundation wall or some distance (2-10 ft) from the wall, depending on local sewer ordinances
  - Also called house connection or service connection
- Lateral sewer – a sewer that discharges into a branch or other sewer and has no other common sewer tributary to it
  - Sometimes called a "street sewer" because it collects wastewater from individual homes
- Branch sewer – a sewer that receives wastewater from a relatively small area and discharges into a main sewer serving more than one branch sewer area

6

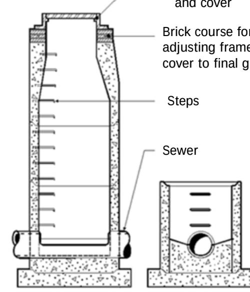
Gravity Collection Sewer

- Main sewer – a sewer line that receives wastewater from many tributary branches and sewer lines and serves as an outlet for a large tributary or is used to feed an intercepting sewer
- Trunk sewer – a sewer that receives wastewater from many tributary branches or sewers and serves a large territory and contributing population
  - Also see main sewer
- Intercepting sewer – a sewer that receives a flow from a number of other large sewers or outlets and conducts the waters to a point for treatment or disposal
  - Often called an interceptor

7

Sewer Manhole

- Place people, equipment and materials into sewer for inspection, maintenance and cleaning.
- May not have steps since hazardous if corroded.
- Minimum barrel diameter **48 inches**.
- Inspected annually.
- Reinforced concrete, brick, fiberglass



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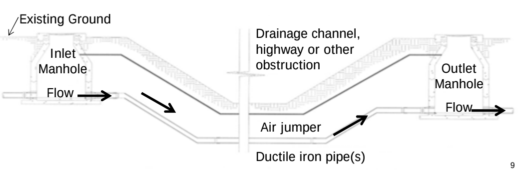
Inverted Siphon

- Sewer lines installed lower than the normal gradient of the sewer line to pass under obstructions such as watercourses and depressed roadways
- Wastewater is pushed through the siphon by the pressure resulting from the upstream sewer being higher than the downstream sewer



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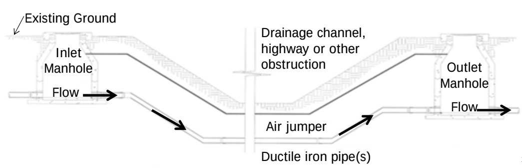
Air Jumper

- Air jumpers are sometimes constructed as part of an inverted siphon.
- Since the siphon is completely filled with wastewater, a blockage in the flow of air in the sewer line occurs without an air jumper.
- This blockage may cause a continuous release of toxic, odorous and corrosive hydrogen sulfide at the upstream siphon manhole.
- Installation of jumpers prevents this from happening by providing the downstream flow of air that usually occurs above the wastewater in a partially filled sewer line.



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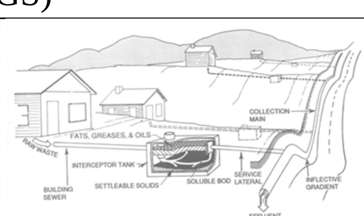
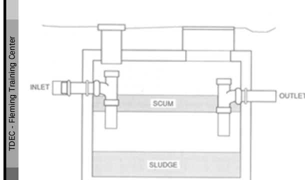
Small Diameter Gravity Sewer (SDGS)



- Septic tanks onsite discharge to small diameter gravity main.
- Discharges effluent by gravity, pump or siphon.
- **Minimum velocity 0.5 ft/sec**.

11

Interceptor Tank



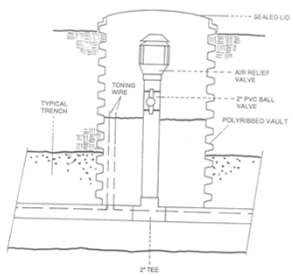
Precast concrete, fiberglass, HDPE or coated steel common.

- Septic tank
- Removes floating and settleable solids
- Levels out flows
- Sludge solids decompose anaerobically
- Regular inspection to measure liquid level, depth of sludge & thickness of scum
- NO tank additive works

12

Vent & Air Release Valve

- Vent maintains flow in SDGS main.
- Air release valve-vents air at high points in main that would restrict flow.
- Gases vented from main often quite odorous- use activated carbon filter, soil bed masking agent.



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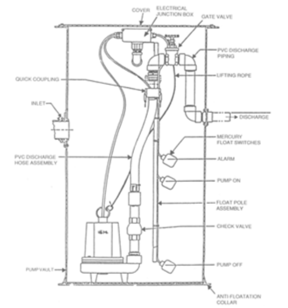
STEP Lift Station

- Simple reinforced concrete or fiberglass wet well after septic tank
- Submersible pump operated by mercury float switches
- Also on gravity mains to allow gravity flow at shallow depth



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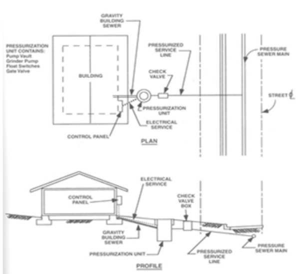
Pressure Sewers



- Flat terrain, rocky soil, high groundwater table
- 4" building sewer at 2% slope
- Septic tank or grinder pump vault
- Pumps & controls
- Valves to isolate system
- Pressure main

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Pressure Sewer Advantages vs. Gravity Sewer

- Deep trenches not necessary
- Inverted siphons not needed to cross roads and rivers
- Smaller pipes often needed
- Fewer stoppages (system pressurized)
- No root intrusion

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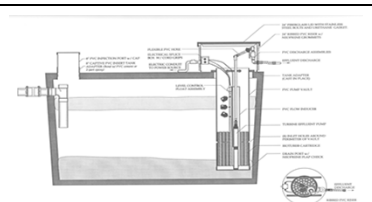
STEP System



- Septic tank effluent pump with filter
- Float activated mercury switch controls pump
- Keep OUT: eggshells, plastic, bones, grease

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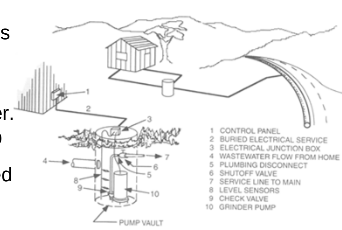
Grinder Pump System

- Submersible centrifugal pump with comminuting blade cuts and shreds solids in WW.
- Pump unit acts to pressurize WW to move it through sewer.
- WW flows from pump vault to pressurized main via a pressurized service line.
- GP serving a home usually 1-2 hp.



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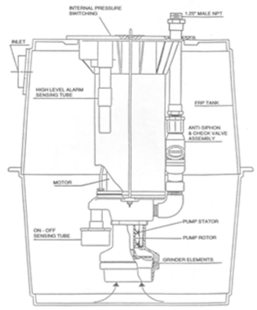
Progressive Cavity Grinder Pump

- Creates pressure that moves WW through sewer
- Reduces size of solids
- Pump, motor, grinder, pipes, valves, controls
- Pressure sensor measures liquid level
- Check & gate valve on discharge prevent backflow
- Excavation not deep: 5-8 ft.
- Odors associated with improper venting.
- Maintenance: solids lodged in cutting blade.



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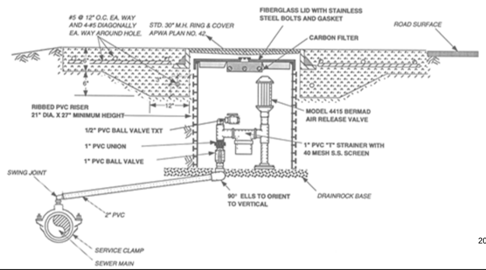
Automatic Air Release Assembly

- Located in high point of pressure sewer
- Release air pockets that would reduce flow capacity.



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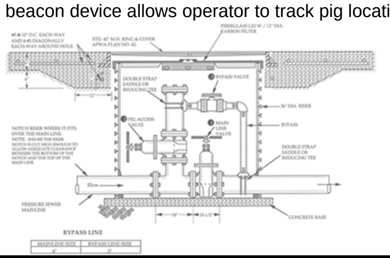
Pigging Port

- Installed to insert pig to clean inside sewer
- as the poly pig is forced through the pipe under pressure.
- Replaces manhole needed in gravity sewer.
- Radio beacon device allows operator to track pig location.



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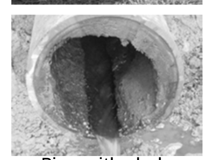
Pigs

- Polyurethane pigs and swabs are slightly larger or the same size as the main to be cleaned.
- Pigging typically done during low flow periods.



Pipe with sludge before cleaning.

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Vacuum Sewer Layout

- 3 Components:
  - On-site valve pit
  - Vacuum collection piping
  - Central vacuum station
- Flat or rolling terrain; unstable soil; high water table; rocky terrain; urban development in rural areas.

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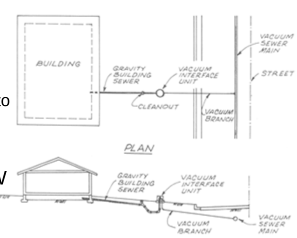
Vacuum Sewer Components

- Gravity building sewer to vacuum interface unit.
- Vacuum interface unit seals vacuum service.
  - Once 3 gal WW accumulate, valve opens to allow atmospheric air to force WW into vacuum branch.
- Vacuum main sends WW to treatment facility.
- Minimum slope vacuum main is 0.2 ft/sec.



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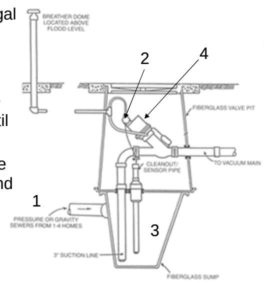
Typical Fiberglass Valve Pit With External Breather

- WW flows by gravity (1) into 30 gal holding tank.
- As WW level rises, air is compressed in sensor tube connected to valve controller (2).
- Sensor signals valve to open until tank contents are evacuated (3).
- The spring-loaded interface valve (4) is controlled pneumatically and needs no electricity.
- External breather is a 1 ¼ inch polyurethane pipe anchored in ground by concrete.
- Breather pipe must be watertight and has domed cover to keep insects out.



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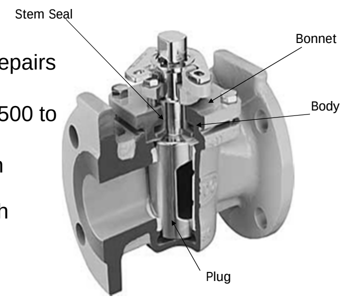
Isolation Valve

- Plug or gate valves isolate portions of vacuum sewer for repairs and maintenance.
- Typical interval is 1500 to 2000 ft.
- Also located at both sides of a bridge crossing and at both sides of an area of unstable soil.



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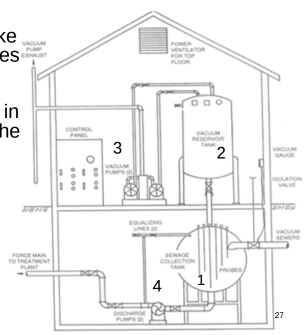
Typical Vacuum Station

- Steel or fiberglass collection tank (1) acts like wet well. Vacuum switches on reservoir tank (2) regulate vacuum pumps (3). Level control probes in collection tank regulate the WW pumps (4).
- Daily operating tasks:
  - Visual check gages and charts
  - Record pump run times
  - Check oil & block temperature



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Typical Vacuum Station

- 1 station serves 200-300 customers
- Vacuum pumps operate 3-5 hrs/day
- Pumps are typically 20 hp

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Vacuum Sewer Advantages

- Small pipe sizes, typically 3, 4, 6, 8 and 10 in
- Easy to avoid underground obstacles
- Shallow installation (2 to 4 ft) eliminates need for wide deep trenches reducing excavation costs and environmental impact
- High scouring velocity reduces blockages and keeps WW aerated and mixed
- No infiltration-leaks easily noted
  - Reduced infiltration leads to reduced size and cost of treatment plant.
- No manholes
- Only power source at vacuum station

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Vacuum Sewer O & M

- No odors problems
  - System is sealed; large air input with flow.
- No corrosion problems
  - Corrosion resistant PVC, ABS, rubber, stainless steel.
- No odors
- Malfunctions:
  - Break in vacuum line
  - Valve malfunction
  - Closed isolation valve
- O&M of vacuum systems are more difficult than a low pressure system because it is harder to maintain a vacuum due to the number of inlets and valves to the system.

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Collection Systems Vocabulary

______1. Alignment
______2. Barrel
______3. Bedding
______4. Building Sewer
______5. Check Valve
______6. Combined Sewer
______7. Exfiltration
______8. Force Main
______9. Grit
______10. Infiltration
______11. Inflow
______12. Lift Station
______13. Manhole
______14. Pneumatic Ejector
______15. Sanitary Sewer
______16. Slope
______17. Storm Sewer
______18. Weir

A. A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.

B. An opening in a sewer provided for the purpose of permitting operators or equipment to enter or leave a sewer. Sometimes called an "access hole" or "maintenance hole."

C. The heavy mineral material present in wastewater such as sand, coffee grounds, eggshells, gravel and cinders. Grit tends to settle out at flow velocities below 2 ft/sec and accumulate in the invert or bottoms of the pipelines.

D. (1) The cylindrical part of a pipe that may have a bell on one end. (2) The cylindrical part of a manhole between the cone at the top and the shelf at the bottom.

E. A pipe or conduit (sewer) intended to carry wastewater or waterborne wastes from homes, businesses and industries to the POTW (Publicly Owned Treatment Works). Storm water runoff or unpolluted water should be collected and transported in a separate system of pipes or conduits (storm sewers) to natural watercourses.

F. A sewer designed to carry both sanitary wastewaters and storm or surface water runoff.

G. A separate pipe, conduit or open channel (sewer) that carries runoff from storms, surface drainage and street wash, but does not include domestic and industrial wastes. They are often the recipients of hazardous or toxic substances due to the illegal dumping of hazardous wastes or spills created by accidents involving vehicles and trains transporting these substances.

H. A gravity-flow pipeline connecting a building wastewater collection system to a lateral or branch sewer. The building sewer may begin at the outside of the building's foundation wall or some distance (such as 2 to 10 feet) from the wall, depending on local sewer ordinances.

I. A device for raising wastewater, sludge or other liquid by compressed air. The liquid is alternately admitted through an inward-swinging check valve into the bottom of an airtight pot. When the pot is filled, compressed air is applied to the top of the liquid. The compressed air forces the inlet valve closed and forces the liquid in the pot through an outward-swinging check valve, thus emptying the pot.

J. The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.
K. The prepared base or bottom of a trench or excavation where a pipe or other underground structure is supported.
L. A wastewater pumping station that lifts the wastewater to a higher elevation when continuing the sewer at reasonable slopes would involve excessive depths of trench. Also, an installation of pumps that raise wastewater from areas too low to drain into available sewers. These situations may be equipped with air-operated ejectors or centrifugal pumps. Sometimes called a pump station, but this term is usually reserved for a similar type of facility that is discharging into a long force main, while a lift station has a discharge line or force main only up to the downstream gravity sewer.
M. A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.
N. The inclination or a sewer trench excavation is the ratio of the vertical distance to the horizontal distance or "rise over run."
O. The proper positioning of parts in a system. The alignment of a pipeline or other line refers to its location and direction.
P. Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy area, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.
Q. Liquid wastes and liquid-carried wastes that unintentionally leak out of a sewer pipe system and into the environment.
R. A wall or plate placed in an open channel and used to measure the flow of water. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used to convert depth to flow.

Collection Systems Questions

1. What is the purpose of a wastewater collection system?

2. List the principal components of a low pressure collection system.

3. List the principal components of a vacuum collection system.

4. What is the purpose of a backflow preventer?

5. What factors control the width of a sewer trench?

6. List the problems that can be caused by poor sewer pipe joints.

7. Some agencies prohibit manhole steps and use ladders instead to
   a. Eliminate hazards of corroded steps.
   b. Increase speed of operators entering manholes.
   c. Protect operators from splashing or falling wastewater.
   d. Save on cost of steps.

8. Experience has shown that the minimum scouring velocity in a sewer should be greater than:
   a. 2 ft/sec
   b. 3 ft/sec
   c. 4 ft/sec
   d. 5 ft/sec

9. The amount of wastewater that a collection system conveys is determined by quantities of:
   a. Commercial wastewaters
   b. Domestic wastewaters
   c. Groundwater infiltration
   d. Sludge produced by wastewater treatment plant
   e. Surface water inflow

10. Construction materials for sewers are selected for their:
    a. Ability to minimize infiltration and exfiltration
    b. Cost of materials
    c. Cost of installation
    d. Resistance to deterioration
    e. Resistance to root intrusion

Answers to Vocabulary and Questions

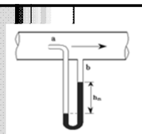
Vocabulary:

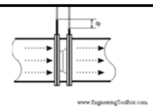
1.	O	7.	Q	13.	B
2.	D	8.	M	14.	I
3.	k	9.	C	15.	E
4.	H	10.	J	16.	N
5.	A	11.	P	17.	G
6.	F	12.	L	18.	R

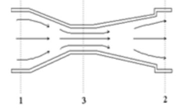
Questions:
1. The purpose of a wastewater collection system is to collect the wastewater from a community's homes and industries and convey it at an appropriate velocity to a wastewater treatment plant.
2. The principal components of a low-pressure collection system include gravity sewers, holding tanks, grinder pumps and pressure mains.
3. The principal components of a vacuum collection system include gravity sewers, holding tanks, vacuum valves, vacuum mains and vacuum pumps.
4. Backflow preventers are used to stop the accidental backflow or reverse flow of wastewater into buildings from the sewer.
5. The width of a sewer trench is controlled by the diameter of the sewer pipe, clearance for pipe laying, soil stability for safety during excavation and the excavation procedures.
6. Poor sewer pipe joints can lead to problems caused by roots, infiltration & exfiltration.
7. a
8. a
9. a, b, c and e
10. All are correct

Section 2

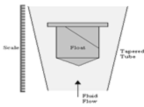
Flow Measurement


Pitot Tube


Orifice Plate


Venturi meter


Parshall Flume


Rotameter

FLOW MEASUREMENT

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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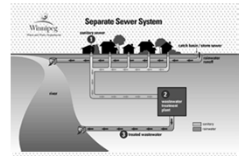
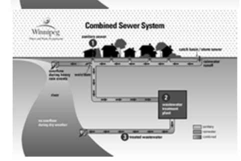
1

WHAT ARE THE WASTEWATER FLOWS?

- Sanitary Sewer:
  - Domestic and industrial waste
- Storm water:
  - snow melt, street wash, etc.
- Combined sewer:
  - sanitary plus storm
- Infiltration/inflow





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2

I/I

- Inflow – Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage.
  - Inflow differs from infiltration in that it is a direct discharge into a sewer rather than a leak in the sewer itself.

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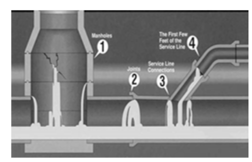
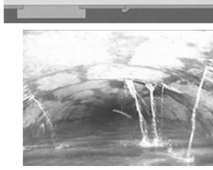
3

I/I

- Infiltration – the seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.
- Exfiltration – liquid wastes and liquid-carried wastes that unintentionally leak out of a sewer pipe system and into the environment





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4

WASTEWATER FLOWS: WHY DO WE CARE?

- Collection and conveyance system design
- Treatment system design
  - Hydraulic criteria: must be able to pass peak flows
  - Treatment criteria: meeting treatment standards depends often on "hydraulic residence time"
    - e.g. MG / MGD = days = residence time
  - Growth projections (population, development)

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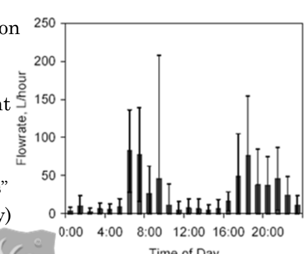
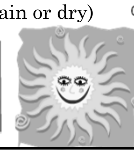
FACTORS EFFECTING FLOW RATES

- Geographical location & socioeconomic conditions
- Type of development
- Season
- Time of Day
  - "Diurnal variations"
- Climate (rain or dry)





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Flow Measurement

- Basics of Flow Measurement
- Open Channel Flow Measurement
  - Primary Elements
  - Secondary Elements
- Closed Pipe Flow Measurement
  - Differential Pressure
  - Mechanical Devices
- Flow Equalization

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Flow is …

- Amount of water going past a reference point over a certain time
- Units: volume per unit time
  - (ft3/sec, gal/min, MGD)
- Calculated by the equation: Q = AV

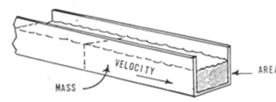

Fig. 15.57 Flow mass

Q = quantity of flow

A = cross-sectional area of flow

V = velocity of flow

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Sewer System Evaluations

- Flow monitoring is primary tool for identifying high inflow/infiltration (I/I)
- System problems:
  - Back flooding into private property due to surcharging of sewer mains
  - Bypassing of untreated wastewater to environment
  - Reduced system capacity

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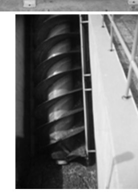
Flow Measurement & Wastewater Treatment

- Unit processes are designed for specific flow levels
- Pumping rates, aeration rates, chemical feed rates, etc. based on current flow
- Accurate flow measurement is key to identify, correct and prevent operational problems



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Flow Metering Equipment Commonly Used in Wastewater Treatment Plants

Type	Accuracy	Advantages	Disadvantages
Open-Channel Flume	5-7%	Low headloss, self-cleaning	Requires careful construction, susceptible to flooding
Open-Channel Weir	5-7%	Low cost, ease of installation	High headloss, requires a well-developed flow profile, cleaning required
Full-Pipe Electro-magnetic	1-3%	No headloss, bi-directional	Minimum conductivity required, expensive, well-developed velocity profile required
Full-Pipe Doppler	2-5%	No headloss, low cost, not affected by air bubbles	Not suitable for some pipe material, well-developed velocity profile required
Full-Pipe Venturi	1-3%	Low headloss, high accuracy	Expensive, well-developed velocity profile required

MOP No. 11 – Operation of Municipal Wastewater Treatment Plants

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Types of Flow Meters

- Different types of flow measuring devices include constant differential, head area, velocity meter, differential head and displacement.
- All flow measurement devices should be calibrated and maintained to ensure the accuracy of the measurement is ± 10% of the true flow.
- Methods that can be used to check the performance of a flow meter are:
  - Measure the area and velocity of an open channel
  - Measure how many minutes it takes to fill a 55-gallon drum
  - Measure how long it takes to fill a tank of a known volume

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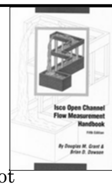
Open Channel Flow Primary Elements



- Creates conditions that produce known relationship between flow and depth
- Channel width is known, but velocity is not needed
- Primary devices:
  - Weirs
  - Flumes
- Secondary element senses depth at measurement point, converting this to flow
- A detailed discussion of different types of weir and flume configurations used in North America is presented in the *Isco Open Channel Flow Measurement Handbook*

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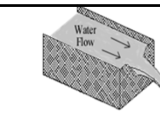
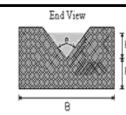
Weir





- Overflow structure; rectangular or V-notch
- Discharge rate determined by measuring vertical distance from crest of overflow to surface of upstream pool
- Disadvantage: Organic solids collect behind weir, causing odors & inaccurate measurements
- Measures liquid flow in partially full channels or basins
- Blocks the flow in the channel
- Depth of water proportional to amount of flow

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Weir

- Used in open channels and is placed across the channel, weirs are made of thin materials and may have either a rectangle or V-notch opening.
- The flow over the weir is determined by the depth of flow going through the opening.
- A disadvantage in using a weir at the influent of the plant is that solids may settle upstream of the weir and cause odors and unsightliness.

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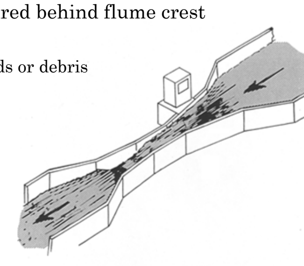
Flume

- Entrance, Throat, Discharge
- Depth is measured behind flume crest
- Best for:
  - Flow with solids or debris
  - Large Flows
  - Variable flows



FLUME

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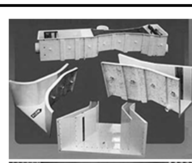
Flumes

- Specially shaped open channel section with entrance, throat & discharge sections
- Constriction causes change in head which can be converted to flow rates
- Used where head loss is a concern, for larger flows or flows with solids or debris



Influent / Effluent Parshall Flume (9" throat)

Palmer-Bowlus flumes measure flow in existing sewers

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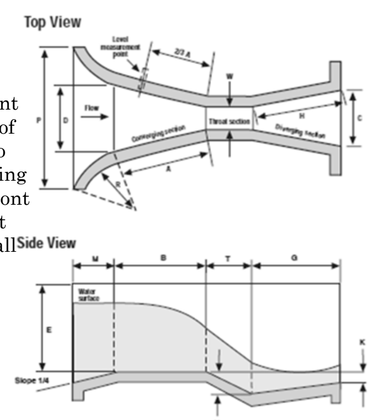
Flumes

- Measurement point is 1/3 of the way into the converging section in front of the throat for a Parshall flume



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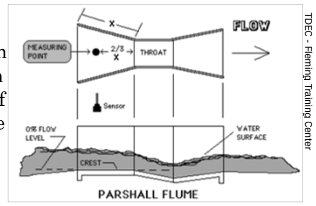
Parshall Flume

- Parshall flume is one of the most common measuring devices.
- It is a narrow place in a open channel which allows the quantity of wastewater flow to be determined by measuring the depth of flow with ultra sonic device, floats or manually with measuring device.



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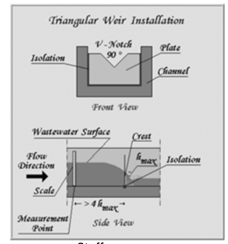
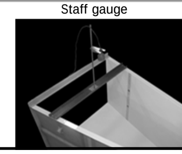
Open Channel Flow Secondary Elements

- Measures or indicates liquid level in primary device
- Used with instruments to convert head to flow
- Selection based on location, type of information required & cost
- **Staff gauge** in stilling well
- **Floats** in stilling well
- **Bubblers**
- **Ultrasonic devices**



Staff gauge



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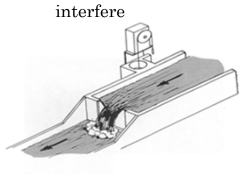
Secondary Elements

- Measure the water level in the Primary Device (weir or flume)
- Example 1 – Float
  - Simple, Inexpensive
  - Grease, solids may interfere



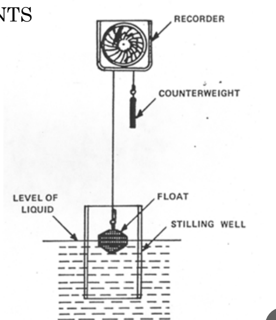


Fig. 6.12 A float is used to measure liquid level and convert the level reading to a flow measurement

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Secondary Elements

- Types of float controls
  - Rod-attached floats
  - Steel tape, cable or rope attached floats
  - Mercury switch floats
  - Ultrasonic
  - Pressure transducers

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Secondary Elements

- Example 2 – Ultrasonic Meter
  - Sound pulse
  - No direct contact with wastewater
  - Limit – Cannot measure less than 3

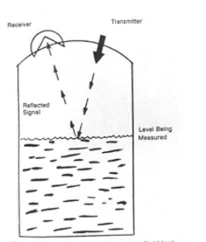
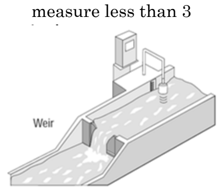
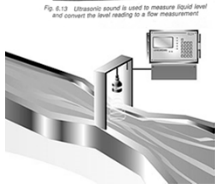


Fig. 6.13 Ultrasonic sound is used to measure liquid level and convert the level reading to a flow measurement





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Secondary Elements

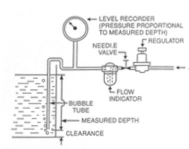
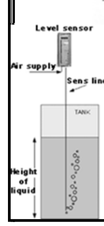


Fig. 6.14 A bubbler tube is used to measure liquid level and convert the depth reading to a flow measurement



- Example 3 – Bubbler Tube
  - Constant flow of air
  - Depth determined by air pressure
  - Generally operate at 5 psi, the depth of the water in the wet well will determine the pressure required.

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Closed Pipe Flow Measurement

- Differential Producers
  - Venturi meter
  - Orifice plate
- Velocity Meters
  - Propeller-type
  - Pitot tube
  - Magnetic meter
- Constant Differential
  - Rotameter

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Closed Pipe Flow Measurement: Differential Producers

- Venturi system
  - Pipe diameter gradually reduces at the throat and returns to original diameter
  - Low pressure is created in throat
  - Difference in pressure indicates amount of flow
  - Simple and inexpensive
  - Need straight runs of pipe before and after
  - Excellent for gases and liquids (not sludge)

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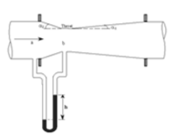
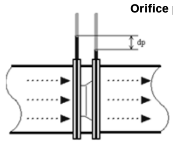
Closed Pipe Flow Measurement: Differential Pressure

- Measure velocity directly or convert velocity head to pressure head by restricting flow in pipe
- Gases & liquids in closed pipes



Venturi meter: liquid passes through reduced throat section & velocity increases. Pressure differential then measured using **manometer**.

Orifice plate



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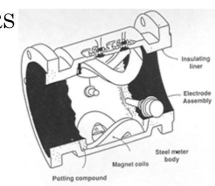
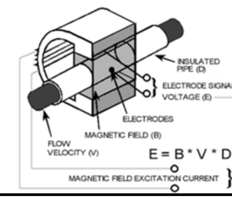
Closed Pipe Flow Measurement: Velocity Meters

- Magnetic Flow Meter
  - Creates magnetic field in water stream
  - Conductor (water) moving through magnetic field produces electric current
  - Measure of electricity indicates amount of flow
  - Very accurate, Low maintenance
  - Can be expensive (esp. for larger diameters)





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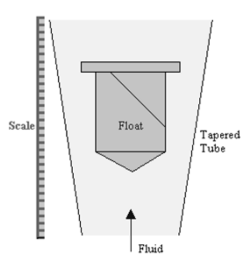
Closed Pipe Flow Measurement: Constant Differential

- Example: Chemical Feed Systems
- Rotameter
  - Float or ball in vertical tube
  - Increased flow causes float to ride higher
  - Simple, accurate, easy
  - Must keep tube and float clean



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Maintenance of Flow Measuring Devices

- Clean devices regularly
  - Grease build up on floats & magnetic meter coils
  - Weir plate clogged with debris
- Periodically inspect devices for damage & deterioration
  - Pneumatic lines may have air leaks
  - Electrical parts may short out
- Recalibrate secondary devices regularly

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Flow Equalization

- Smoothes out fluctuations in flow volume and pollutant concentrations
- Provides for constant flow with less variations in loading
- Improves performance of downstream processes
- TN Design Criteria says you must maintain a 1.0 mg/L DO throughout the EQ tank

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Flow Equalization

- Types:
  - Surge – prevents flows above max. hydraulic capacity
  - Diurnal – reduces the magnitude of daily flow variations
  - Complete – eliminates flow variations
- Two Schemes
  - In-line equalization
  - Side-line equalization

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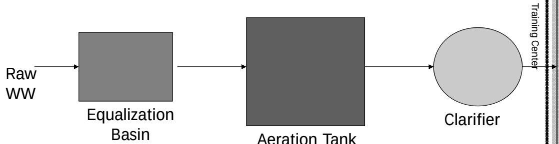
Flow Equalization: In-Line

- All flow enters equalization basin before entering STP.
- Flow is stored as required and later released as steady flow.



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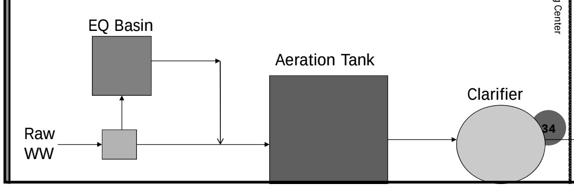
Flow Equalization: Side-Line

- Equalization basin in collection system or at STP.
- Only flow greater than daily average is diverted to basin.
- Can occur after screening and grit removal, eliminating major grit and settleable solids problems.



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Flow Equalization

- Requires mechanical or diffused air mixing, pumps & flow measurement
- Blend entire tank contents
- Benefits:
  - Increased DO
  - Better grease separation
  - Better settling in primary
  - Better settling in final
  - 10% - 20% BOD reduction
  - Improved response to shock loads

Landsdale, PA 2.5 MG equalization basin

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Flow Measurement Vocabulary

______1. Analog
______2. Composite
______3. Conductivity
______4. Density
______5. Digital Readout
______6. Head
______7. Head Loss
______8. Manometer
______9. Orifice
______10. Primary Element
______11. Secondary Element
______12. Sensor
______13. Surcharge
______14. Totalizer
______15. Venturi Meter

A. An opening (hole) in a plate, wall or partition. An orifice flange or plate placed in a pipe consists of a slot or a calibrated circular hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be used to determine the flow in the pipe.
B. A measure of the ability of a solution (water) to carry an electric current.
C. The secondary measuring device or Flowmeter used with a primary measuring device (element) to measure the rate of liquid flow. In open channels bubblers and floats are secondary elements. Different pressure measuring devices are the secondary elements in pipes or pressure conduits.
D. The readout of an instrument by a pointer (or other indicating means) against a dial or scale. Also the continuously variable signal type sent to an analog instrument.
E. An indirect measure of loss of energy or pressure. Flowing water will lose some of its energy when it passes through a pipe, bar screen, Comminutor, filter or other obstruction. This is measured as the difference in elevation between the upstream water surface and the downstream water surface and may be expressed in feet or meters. Flow measuring devices like venturi tubes and orifice plates use it.
F. The supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.
G. The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.
H. A measure of how heavy a substance (solid, liquid or gas) is for its size. It is expressed in terms of weight per unit volume, which is grams per cubic centimeter or pounds per cubic foot. The density of water (at 4° C or 39° F) is 1.0 gram per cubic centimeter or about 62.4 pounds per cubic foot.
I. A device or meter that continuously measures and calculates a process rate variable in cumulative fashion.
J. An instrument for measuring pressure. Usually it is a glass tube filled with a liquid that is used to measure the difference in pressure across a flow-measuring device such as an orifice or a Venturi meter.
K. A collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the

others in proportion to the rate of flow when the sample was collected. The resulting mixture forms a representative sample and is analyzed to determine the average conditions during the sampling period.

L. A flow-measuring device placed in a pipe. The device consists of a tube whose diameter gradually decreases to a throat and then gradually expands to the diameter of the pipe. The flow is determined on the basis of the difference in pressure (caused by different velocity heads) between the entrance and throat of the device.

M. The use of numbers to indicate the value or measurement of a variable. The readout of an instrument by a direct, numerical reading of the measured value.

N. A device that measures a physical condition or variable of interest. Floats and thermocouples are examples of these.

O. The hydraulic structure used to measure flows. In open channels weirs and flumes are primary elements or devices. Venturi meters and orifice plates are the primary elements in pipes or pressure conduits.

Flow Measurement Questions

1. When do open channel flow conditions occur?

2. What are the commonly used methods of measuring plant flows?

3. Where are flumes used instead of weirs to measure flows?

4. What are the two basic types of flow systems?

5. What are the three different sections of a flume?

6. What are the advantages of an electromagnetic/magnetic flow meter?

7. Why measure flows before and after an equalization basin?

Answers to Vocabulary and Questions

Vocabulary:

1. D	6. G	11. C
2. K	7. E	12. N
3. B	8. J	13. F
4. H	9. A	14. I
5. M	10. O	15. L

Questions:

1. When the flow upstream has a free or unconfined surface that is open to the air.
2. Velocity area and use of a hydraulic structure.
3. Where head loss is a concern, larger flows or flows with debris.
4. open channel flow and closed channel (or closed pipe)
5. ① the entrance section (converging section), ② throat section and ③ discharge (diverging) section
6. an obstruction less design, high accuracy and an output signal that is directly proportional to the flow rate
7. in order to control the basin's operation and optimize its effectiveness

Section 3

Math Review

1

Area, Volume and Conversions

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Area

- Surface of an object
- Two dimensional
- Measured in:
  - Square inches
  - Square feet
  - Square meters, etc.

3

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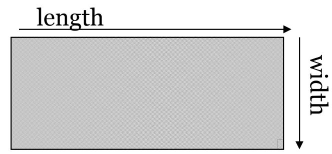
Area Formulas

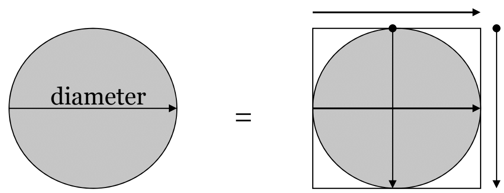
- Rectangle

A = (length, ft)(width, ft)



- Circle

A = $(0.785)(\text{diameter, ft})^2$



Diameter is equal to length and width of a square and a circle takes up 78.5% of square

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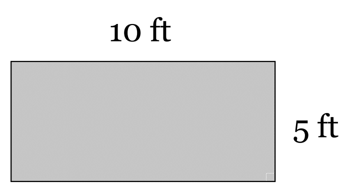
Area of a Rectangle

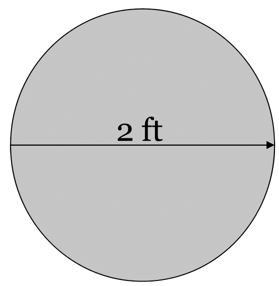


A = (l, ft)(w, ft)

A = (10 ft)(5 ft)

A = 50 ft^2

Area of a Circle



Diameter = 2 ft

$$A = (0.785)(D, ft)^2$$

$$A = (0.785)(2ft)(2ft)$$

$$A = 3.14\ ft^2$$

Volume

- The amount of space an object occupies
- Volume = (area)(third dimension) or

  $$V = (l)(w)(d)$$

- Measured in:
  - Cubic inches
  - Cubic feet
  - Gallons
  - Acre-feet, etc.

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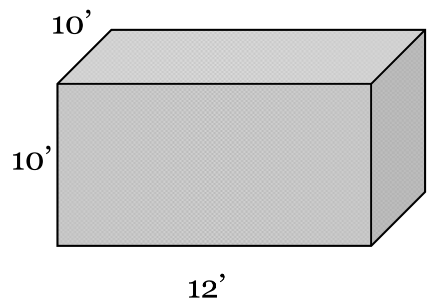
Volume of a Rectangular Tank, ft^3

V = (length, ft)(width, ft)(depth, ft)

$V = (12\ ft)(10ft)(10ft)$

$V = 1200\ ft^3$



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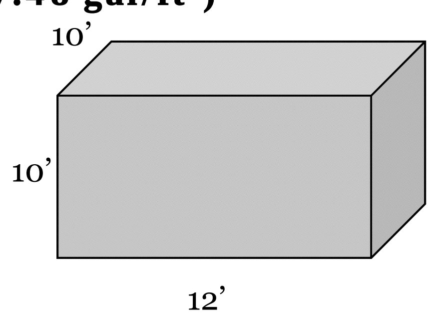
Volume of a Rectangular Tank, gal

$V,\ ft^3 = 1200\ ft^3$

$V,\ gal = (Volume,\ ft^3)(7.48\ gal/ft^3)$

$V,\ gal = (1200\ ft^3)(7.48)$

$V,\ gal = 8976\ gal$

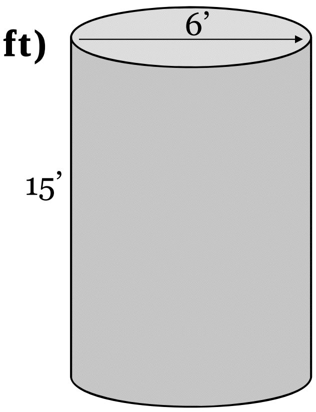


Volume of a Cylinder, ft^3

$V = (0.785)(D, ft)^2(height, ft)$

$V = (0.785)(6\ ft)(6\ ft)(15\ ft)$

$V = 424\ ft^3$



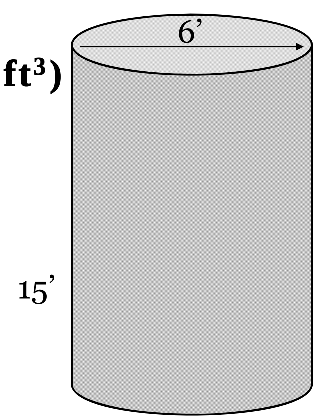
Volume of a Cylinder, gallons

$V, ft^3 = 424\ ft^3$

$V, gal = (Volume, ft^3)(7.48\ gal/ft^3)$

$V, gal = (424\ ft^3)(7.48)$

$V, gal = 3171.52\ gal$



11

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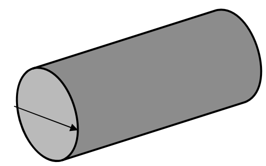
Note

- When calculating area and volume, if you are given a pipe diameter in inches, convert it to feet.
- 8 in. ÷ 12 in/ft = 0.6667 ft



Diameter = 8 in

12

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Conversions

- Need to know:
- The number that relates the two units
  - Ex: 12 inches in a foot, 454 grams in a pound, 3785 mL in a gallon
- Whether to multiply or divide
  - Ex: smaller to larger or larger to smaller

13

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Conversions

Conversion Factors

1 acre	=	43,560 ft^2
1 foot of head	=	0.433 psi
1 psi	=	2.31 feet of head
1 yd^3	=	27 ft^3
1 gal	=	3.785 Liters
1 gallon of water	=	8.34 lbs
1 cubic foot of water	=	7.48 gallons
1 lb	=	453.6 grams
1 mile	=	5280 feet
1%	=	10,000 $^{mg}/_{L}$

Multiply

- Just looking at the units, if you are given miles and you need feet, we are going from left to right on the page, therefore multiply

14

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Conversions

- You have just laid ⅝ mile of sewer line. How many feet is this?

$$5 \div 8 = 0.625 \text{ miles}$$

$$(0.625 \text{ miles})(5280 \text{ feet/mile}) = 3300 \text{ feet}$$

15
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Percent to Decimal

Percent = per one hundred

20%	=	20/100	=	0.20
5%	=	5/100	=	0.05
12.25%	=	12.25/100	=	0.1225
0.5%	=	0.5/100	=	0.005

Move decimal 2 places to the left.

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Velocity

- Distance per time
- Measured in:
  - Miles per hour
  - Feet per second
  - Feet per minute

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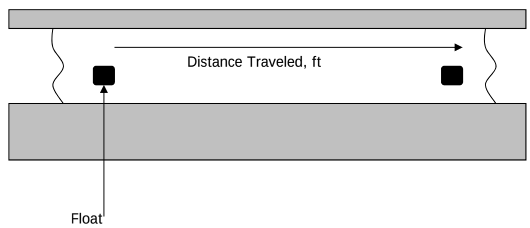
Velocity Formulas

- Velocity, ft/sec = $\frac{\text{distance traveled, ft}}{\text{time, sec}}$
- Velocity, ft/min = $\frac{\text{distance traveled, ft}}{\text{time, min}}$



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Velocity

- A cork is placed in a channel and travels 400 feet in 2 minutes and 25 seconds. What is the velocity of the wastewater in the channel, ft/min?

- 25 seconds/60 = 0.4167
- Vel = $\frac{400 \text{ ft}}{2.4167 \text{ min}}$ = 165.5 ft/min

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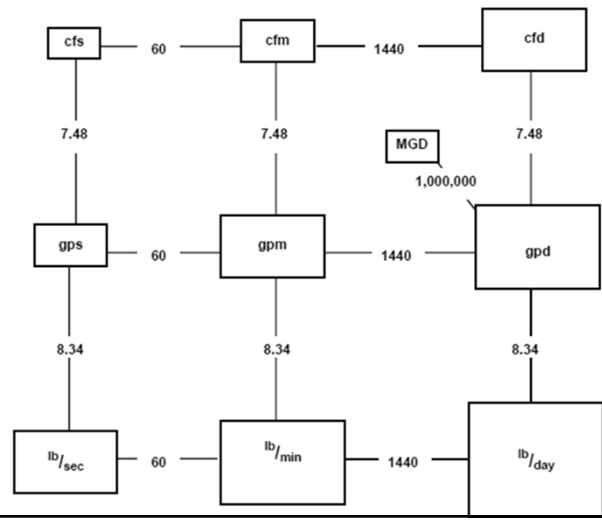
Flow Conversions – Box Method

Small to Big → multiply

Big to Small → divide



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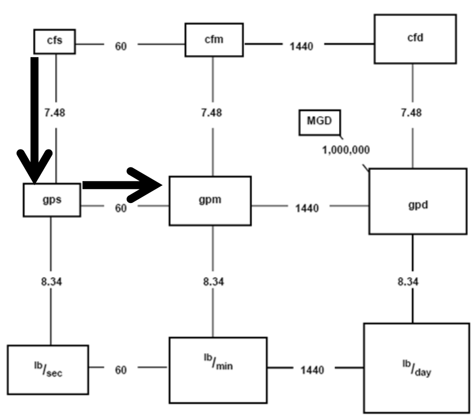
Flow Conversions – Box Method

- Convert a flow of 2.7 cfs to gpm.



$(2.7)(7.48)(60) = 1211$ gpm

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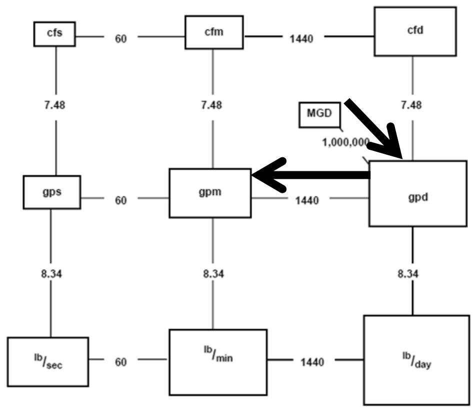
Flow Conversions – Box Method

- Convert a flow of 1.0 MGD to gpm.



$$\frac{(1.0)(1,000,000)}{1440} = 694 \text{ gpm}$$

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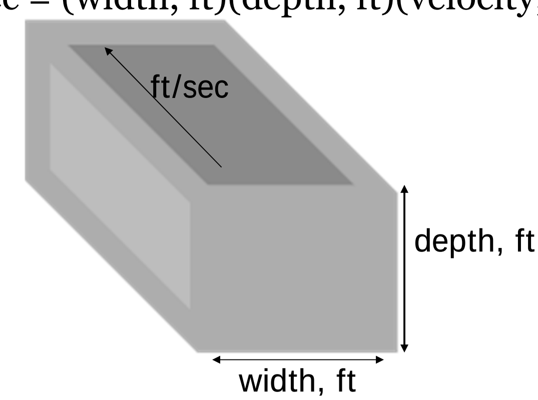
Flow in a Channel

- Q, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)
- Q, ft^3/sec = (width, ft)(depth, ft)(velocity, ft/sec)



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Flow in a Channel

- A channel 36 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 1.2 ft/sec, what is the flow in the channel in ft^3/sec?
- Q, ft^3/sec = (width, ft)(depth, ft)(velocity, ft/sec)
- Q = (3ft)(2 ft)(1.2 ft/sec)

  = 7.2 ft^3/sec

24

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Flow in a Pipe Flowing Full

- Q, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)
- Q, ft^3/sec = (0.785)(Diameter, ft)^2(velocity, ft/sec)

25

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Flow in a Pipe Flowing Full

- The flow through a 10-inch diameter sewer is flowing full at 2.5 ft/sec. What is the flow rate in ft^3/sec and gal/day?
- Q, ft^3/sec = (0.785)(Diameter, ft)^2(velocity, ft/sec)
- Q = (0.785)(0.8333)(0.8333)(2.5) = 1.36 ft^3/sec
- (1.36 ft^3/sec)(7.48 gal/ft^3)(60 sec/min)(1440 min/day) = 880,699.5 gal/day

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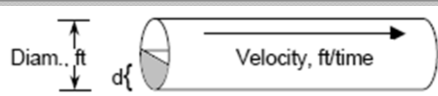


Flow in a Partially Full Pipe

- Q = (factor from d/D table)(Diameter, ft)^2(vel, fps)

depth/Diameter Table							
0.01	0.0013	0.26	0.1623	0.51	0.4027	0.76	0.6404
0.02	0.0037	0.27	0.1711	0.52	0.4127	0.77	0.6489
0.03	0.0069	0.28	0.1800	0.53	0.4227	0.78	0.6573
0.04	0.0105	0.29	0.1890	0.54	0.4327	0.79	0.6655
0.05	0.0147	0.30	0.1982	0.55	0.4426	0.80	0.6736
0.06	0.0192	0.31	0.2074	0.56	0.4526	0.81	0.6813
0.07	0.0242	0.32	0.2167	0.57	0.4625	0.82	0.6893
0.08	0.0294	0.33	0.2260	0.58	0.4724	0.83	0.6969
0.09	0.0350	0.34	0.2355	0.59	0.4822	0.84	0.7043
0.10	0.0409	0.35	0.2450	0.60	0.4920	0.85	0.7115
0.11	0.0470	0.36	0.2546	0.61	0.5018	0.86	0.7186
0.12	0.0534	0.37	0.2642	0.62	0.5118	0.87	0.7254
0.13	0.0600	0.38	0.2739	0.63	0.5212	0.88	0.7320
0.14	0.0668	0.39	0.2836	0.64	0.5308	0.89	0.7384
0.15	0.0739	0.40	0.2934	0.65	0.5404	0.90	0.7445
0.16	0.0811	0.41	0.3032	0.66	0.5499	0.91	0.7504
0.17	0.0885	0.42	0.3130	0.67	0.5594	0.92	0.7560
0.18	0.0961	0.43	0.3229	0.68	0.5687	0.93	0.7612
0.19	0.1039	0.44	0.3328	0.69	0.5780	0.94	0.7662
0.20	0.1118	0.45	0.3428	0.70	0.5872	0.95	0.7707
0.21	0.1199	0.46	0.3527	0.71	0.5964	0.96	0.7749
0.22	0.1281	0.47	0.3627	0.72	0.6054	0.97	0.7785
0.23	0.1365	0.48	0.3727	0.73	0.6143	0.98	0.7816
0.24	0.1449	0.49	0.3827	0.74	0.6231	0.99	0.7841
0.25	0.1535	0.50	0.3927	0.75	0.6318	1.00	0.7854

Flow in a Partially Full Pipe

- A 10-inch diameter pipeline has water flowing at a depth of 4 inches. What is the gal/min flow if the velocity of the wastewater is 3.1 fps?

- **Q = (factor from d/D table)(Diameter, ft)^2(vel, fps)**
- d/D = 4 inches of water ÷ 10-inch diameter
  = 4/10 = 0.4 ~ 0.2934
- Q = (0.2934)(0.8333)(0.8333)(3.1) = 0.6316 ft^3/sec
- (0.6316 ft^3/sec)(7.48 gal/ft^3)(60 sec/min) = 408,169 gpm

Math Problem Strategies

Use these rules of operation to approach math problems (*especially when working with formulas*):

1) Work from left to right.
2) Do all the work inside the parentheses first.
3) Do all the multiplication/division above the line (numerator) and below the line (denominator).
4) Then do all the addition and subtraction above and below the line.
5) Perform the division (divided the numerator by the denominator).

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

Known

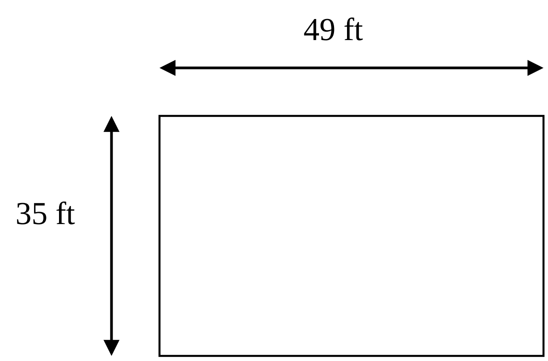
Length = 35 ft
Width = 49 ft

Unknown

Area = ?

A = (l)(w)

A = (35 ft)(49 ft)
A = 1715 ft^2

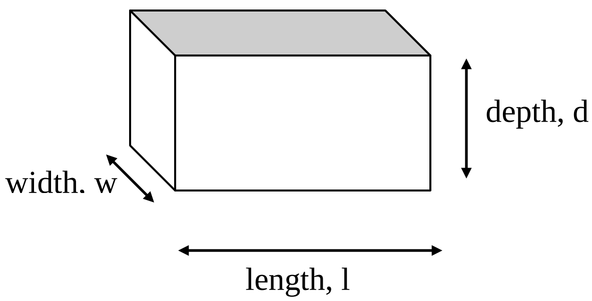


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

mega (M)	..	kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)	..	micro (µ)
1,000,000		1,000	100	10	1	$^{1}/_{10}$	$^{1}/_{100}$	$^{1}/_{1,000}$		$^{1}/_{1,000,000}$

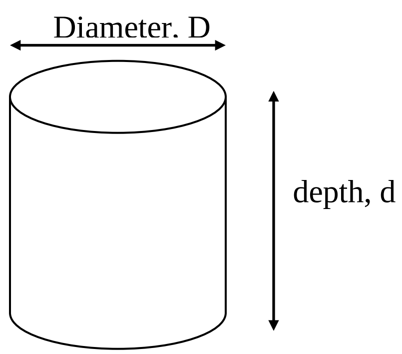
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



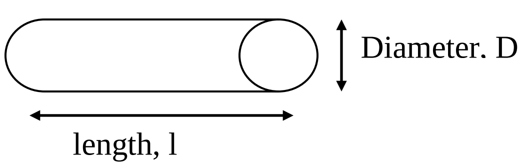
Volume = (l)(w)(d)

Cylindrical Tank



Volume = (0.785) (D $)^2$ (d)

Portion of a Pipeline



Volume = (0.785) (D $)^2$ (l)

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19{,}747 = (20)(12)(x)(7.48)$

12. $\dfrac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\dfrac{x}{(4.5)(8.34)} = 213$

14. $\dfrac{x}{246} = 2.4$

15. $6 = \dfrac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\dfrac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \dfrac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \dfrac{1{,}270{,}000}{x}$

20. $0.59 = \dfrac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $(0.785)(D^2) = 5024$

22. $(x^2)(10)(7.48) = 10,771.2$

23. $51 = \dfrac{64,000}{(0.785)(D^2)}$

24. $(0.785)(D^2) = 0.54$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Percent Practice Problems

Convert the following fractions to decimals:

1. $\frac{3}{4}$
2. $\frac{5}{8}$
3. $\frac{1}{4}$
4. $\frac{1}{2}$

Convert the following percents to decimals:

5. 35%
6. 99%
7. 0.5%
8. 30.6%

Convert the following decimals to percents:

9. 0.65
10. 0.125
11. 1.0
12. 0.05

Calculate the following:

13. 15% of 125
14. 22% of 450
15. 473 is what % of 2365?
16. 1.3 is what % of 6.5?

Answers for Solving for the Unknown

Basics – Finding x

1.	1.8	8.	360	15.	2817
2.	5.7	9.	1649	16.	4903
3.	5.3	10.	244.7	17.	547,616
4.	5,976,990	11.	11	18.	117
5.	8256.6	12.	5	19.	508,000
6.	8.1	13.	7994	20.	0.35
7.	0.005	14.	590.4		

Finding x^2

21.	80	23.	40	25.	10.9
22.	12	24.	0.83		

Percent Practice Problems

1.	0.75	7.	0.005	13.	18.75
2.	0.625	8.	0.306	14.	99
3.	0.25	9.	65%	15.	20%
4.	0.5	10.	12.5%	16.	20%
5.	0.35	11.	100%		
6.	0.99	12.	5%		

Area, Volume and Conversions

AREA

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. A tank has a length of 90 feet, a width of 25 feet, and a depth of 10 feet. Calculate the surface area in ft^2.

3. Calculate the cross-sectional area (in ft^2) for a 2 foot main that has just been laid.

4. Calculate the cross-sectional area (in ft^2) for a 24" main that has just been laid.

5. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

VOLUME

6. Calculate the volume (in ft^3) of a tank that measures 10 feet by 10 feet by 10 feet.

7. Calculate the volume (in gallons) of a basin that measures 22 feet by 11 feet by 5 feet deep.

8. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide, and 10 feet deep if the tank only contains 2 feet of water.

9. Calculate the volume of water in a tank (in gallons) that is 12 feet long by 6 feet wide by 5 feet deep and contains 8 inches of water.

10. Calculate the maximum volume of water (in gallons) for a kids' swimming pool that measures 6 feet across and can hold 18 inches of water.

11. How much water (in gallons) can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

12. A water main has just been laid and needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

13. A water main is 10" in diameter and has a length of 5,000 feet. How many million gallons of water will it hold?

14. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to figure 5% of the tank volume. How many gallons will this be?

15. What is 5% of a 1.2 MG tank?

CONVERSIONS

16. How many seconds in 1 minute?

17. How many minutes in 1 hour?

18. How many hours in 1 day?

19. How many minutes in 1 day?

20. The flow through a pipe is 3.6 cfs. What is the flow in gps?

21. The flow through a pipe is 2.4 cfs. What is the flow in gpm?

22. A pump produces 22 gpm. How many cubic feet per hour is that?

23. A treatment plant produces a flow of 6.31 MGD. What is the flow in gpm?

24. A pump produces 700 gpm. How many MGD will the pump flow?

25. A three-eights mile segment of pipeline is to be repaired. How many feet of pipeline is this?

26. If there is a 2,200 gallon tank full of water, how many pounds of water is in the tank?

ANSWERS:

1. $540\ ft^2$
2. $2,250\ ft^2$
3. $3.14\ ft^2$
4. $3.14\ ft^2$
5. $0.0218\ ft^2$
6. $1,000\ ft^3$
7. 9,050.8 gal
8. 235,590 gal
9. 359 gal
10. 317 gal
11. 288 gal
12. 48,442 gal
13. 0.02 MG
14. 150,000 gal
15. 60,000 gal or 0.06 MG
16. 60
17. 60
18. 24
19. 1440
20. 26.9 gps
21. 1,077 gpm
22. $176.5\ ft^3/hr$
23. 4,382 gpm
24. 1.008 MGD
25. 1,980 ft
26. 18,348 lbs

Basic Math Review for Collection Systems
Flow Conversions
(round to the nearest tenth)

1. Express a flow of 5 cfs in terms of gpm.

2. What is 38 gps expressed as gpd?

3. Convert a flow of 4,270,000 gpd to cfm.

4. What is 5.6 MGD expressed as ft^3/sec?

5. Express 423,690 cfd as gpm.

6. Convert 2730 gpm to gpd.

Answers:

1. 2244 gpm
2. 3,283,200 gpd
3. 396 ft^3/min
4. 8.7 ft^3/sec
5. 2201 gpm
6. 3,931,200 gpd

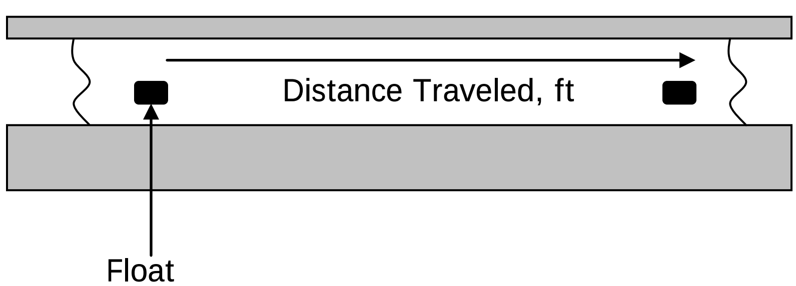
Applied Math for Collections
Flow and Velocity

<u>Velocity</u>

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

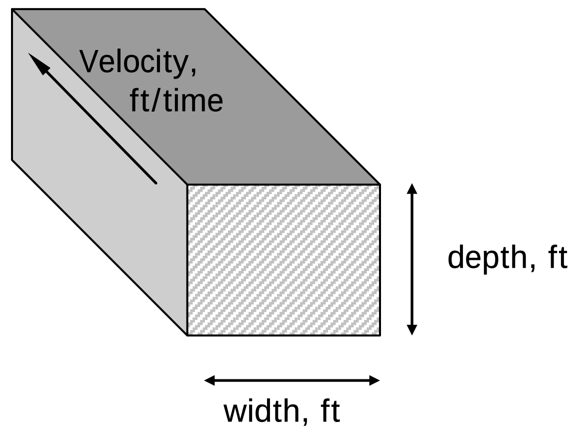
2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$



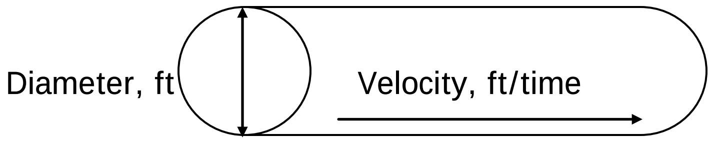
$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?



$$\begin{array}{cccc} Q & = & (A) & (V) \\ ft^3/\text{time} & & ft^2 & (ft/\text{time}) \end{array}$$

$$\begin{array}{cccc} Q & = & (0.785)\ (D)^2 & (\text{vel}) \\ ft^3/\text{time} & & (ft)(ft) & (ft/\text{time}) \end{array}$$

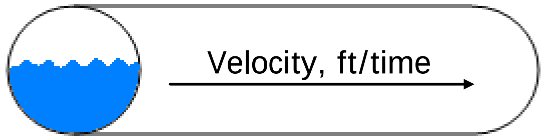
<u>Flow through full pipe</u>

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

10. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

Diameter, ft 

$$\underset{ft^3/time}{Q} = \underset{ft^2}{(\ A\ )}\ \underset{(ft/time)}{(\ V\ )}$$

$$\underset{ft^3/time}{Q} = \overbrace{(\text{Factor from d/D Table})\ \underset{(ft)(ft)}{(\ D\ )^2}}\ \underset{(ft/time)}{(\ vel\ )}$$

<u>Flow through pipe flowing less than full</u>

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm?

Answers:

1. 185 ft/min
2. 2.2 ft/sec
3. 210 ft/min
4. 16.8 ft^3/sec
5. 900 ft^3/min and 9.69 MGD
6. 1.8 ft
7. 10 ft^3/sec
8. 0.59 ft^3/sec
9. 532 gpm
10. 6 in
11. 881 gpm
12. 563,980 gpd
13. 240 ft/min

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

$8.1 = (4.5)(x)$

$\frac{8.1}{4.5} = x$

$\boxed{1.8 = x}$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

$(0.0854865)(x) = 0.49$

$x = \frac{0.49}{0.0854865}$

$\boxed{= 5.7}$

Flip Flop

only when x is on bottom

3. $\frac{233}{x} = \frac{44}{1}$

$\frac{233}{44} = x$

$\boxed{5.3 = x}$

4. $940 = \frac{x}{(0.785)(90)(90)}$

$\frac{940}{1} = \frac{x}{6358.5}$

$(940)(6358.5) = x$

$\boxed{5,976,990 = x}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

$x = \frac{4128.3}{0.5} = \boxed{8256.6}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

$x = \frac{3800}{(56.5)(8.34)} = \frac{3800}{471.21} = \boxed{8.1}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

$114 = \frac{2205.93}{(3846.5)(x)}$

$x = \frac{2205.93}{(3846.5)(114)} = \frac{2205.93}{438501} = \boxed{0.005}$

8. $\frac{2}{1} = \frac{x}{180}$

$(2)(180) = x$

$\boxed{360 = x}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

$\frac{46}{1} = \frac{(875.7)(x)}{31400}$

$(46)(31400) = (875.7)(x)$

$\frac{1444400}{875.7} = x = \boxed{1649}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

$2.4 = \frac{587.18}{x}$

$x = \frac{587.18}{2.4} = \boxed{244.7}$

11. $19{,}747 = (20)(12)(x)(7.48)$

$19{,}747 = (1795.2)(x)$

$\frac{19{,}747}{1795.2} = x$

$\boxed{11 = x}$

12. $\frac{(15)(12)(1.25)(7.48)}{x} = 337$

$\frac{1683}{x} = 337$

$\frac{1683}{337} = x$

$\boxed{5 = x}$

13. $\frac{x}{(4.5)(8.34)} = 213$

$\frac{x}{37.53} = 213$

$x = (213)(37.53)$

$= \boxed{7994}$

14. $\frac{x}{246} = 2.4$

$x = (2.4)(246)$

$\boxed{x = 590.4}$

15. $6 = \frac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

$6 = \frac{(x)(1.5012)}{704.73}$

$(6)(704.73) = (x)(1.5012)$

$\frac{4228.38}{1.5012} = x$

$\boxed{2817 = x}$

16. $\frac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

$\frac{90072}{(0.785)(x)} = 23.4$

$\frac{90072}{(0.785)(23.4)} = \frac{90072}{18.369} = \boxed{4903}$

17. $109 = \frac{x}{(0.785)(80)(80)}$

$109 = \frac{x}{5024}$

$(109)(5024) = x$

$\boxed{547{,}616 = x}$

18. $(x)(3.7)(8.34) = 3620$

$(x)(30.858) = 3620$

$x = \frac{3620}{30.858}$

$\boxed{x = 117}$

19. $2.5 = \frac{1{,}270{,}000}{x}$

$x = \frac{1{,}270{,}000}{2.5}$

$\boxed{x = 508{,}000}$

20. $0.59 = \frac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

$0.59 = \frac{(3431.076)}{(x)(16513.2)}$

$x = \frac{(3431.076)}{(0.59)(16513.2)}$

$= \frac{3431.076}{9742.788}$

$\boxed{= 0.35}$

Finding x^2

21. $(0.785)(D^2) = 5024$

$$D^2 = \frac{5024}{0.785} = 6400$$

$$D = \sqrt{6400} = \boxed{80}$$

22. $(x^2)(10)(7.48) = 10{,}771.2$

$$(x^2)(74.8) = 10{,}771.2$$

$$x^2 = \frac{10{,}771.2}{74.8} = 144$$

$$x = \sqrt{144} = \boxed{12}$$

23. $51 = \dfrac{64{,}000}{(0.785)(D^2)}$

$$D^2 = \frac{64{,}000}{(0.785)(51)} = \frac{64{,}000}{40.035} = 1598.6012$$

$$D = \sqrt{1598.6012} = \boxed{39.98 \approx 40}$$

24. $(0.785)(D^2) = 0.54$

$$D^2 = \frac{0.54}{0.785} = 0.687898$$

$$D = \sqrt{0.687898} = \boxed{0.83}$$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

$$\frac{2.1}{1} = \frac{(88.077)(D^2)}{5024}$$

$$(2.1)(5024) = (88.077)(D^2)$$

$$\frac{10550.4}{88.077} = D^2$$

$$119.786 = D^2$$

$$D = \sqrt{119.786} = \boxed{10.9}$$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾ $\frac{3}{4} = 0.75$
2. ⅝ $\frac{5}{8} = 0.625$
3. ¼ $\frac{1}{4} = 0.25$
4. ½ $\frac{1}{2} = 0.5$

Convert the following percents to decimals:

5. 35% $\frac{35}{100} = 0.35$
6. 99% $\frac{99}{100} = 0.99$
7. 0.5% $\frac{0.5}{100} = 0.005$
8. 30.6% $\frac{30.6}{100} = 0.306$

Convert the following decimals to percents:

9. 0.65 $(0.65)(100) = 65\%$
10. 0.125 $(0.125)(100) = 12.5\%$
11. 1.0 $(1.0)(100) = 100\%$
12. 0.05 $(0.05)(100) = 5\%$

Calculate the following: of means "multiply"; is means "equal to"

13. 15% of 125 $(0.15)(125) = 18.75$
14. 22% of 450 $(0.22)(450) = 99$
15. 473 is what % of 2365? $473 = (x)(2365) \rightarrow \frac{473}{2365} = x \rightarrow 0.2 = x = 20\%$ decimal form
16. 1.3 is what % of 6.5? $1.3 = (x)(6.5) \rightarrow \frac{1.3}{6.5} = x \rightarrow 0.2 = x$ $20\% = x$

APPLIED MATH FOR DISTRIBUTION
AREA, VOLUME, AND CONVERSIONS

Area, Volume and Conversions

AREA

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

$$A = (\text{length})(\text{width})$$
$$= (45\text{ ft})(12\text{ ft})$$
$$\boxed{= 540\text{ ft}^2}$$

2. A tank has a length of 90 feet, a width of 25 feet, and a depth of 10 feet. Calculate the surface area in ft^2.

$$A = (90\text{ ft})(25\text{ ft})$$
$$= \boxed{2250\text{ ft}^2}$$

3. Calculate the cross-sectional area (in ft^2) for a 2 foot main that has just been laid.

$$A = (0.785)(\text{Diameter})^2$$
$$= (0.785)(2\text{ ft})^2$$
$$\boxed{= 3.14\text{ ft}^2}$$

4. Calculate the cross-sectional area (in ft^2) for a 24" main that has just been laid.

$$\frac{24\text{ in}}{} \bigg| \frac{1\text{ ft}}{12\text{ in}} = 2\text{ ft}$$

$$A = (0.785)(2\text{ ft})^2$$
$$= \boxed{3.14\text{ ft}^2}$$

5. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

$$\frac{2\text{ in}}{} \bigg| \frac{1\text{ ft}}{12\text{ in}} = 0.1667\text{ ft}$$

$$A = (0.785)(0.1667\text{ ft})^2$$
$$\boxed{= 0.02\text{ ft}^2}$$

Area and Volume

VOLUME

6. Calculate the volume (in ft^3) of a tank that measures 10 feet by 10 feet by 10 feet.

$$V = (\text{length})(\text{width})(\text{depth})$$
$$= (10\,ft)(10\,ft)(10\,ft)$$
$$\boxed{= 1000\,ft^3}$$

7. Calculate the volume (in gallons) of a basin that measures 22 feet by 11 feet by 5 feet deep.

$$V = (22\,ft)(11\,ft)(5\,ft)$$
$$= \frac{1210\,\cancel{ft^3}}{} \Big| \frac{7.48\,gal}{1\,\cancel{ft^3}}$$
$$= \boxed{9050.8\,gal}$$

8. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide, and 10 feet deep if the tank only contains 2 feet of water.

$$V = (254\,ft)(62\,ft)(2\,ft)(7.48\,gal/ft^3)$$
$$= \boxed{235590\,gal}$$

9. Calculate the volume of water in a tank (in gallons) that is 12 feet long by 6 feet wide by 5 feet deep and contains 8 inches of water.

$$\frac{8\,\cancel{in}}{} \Big| \frac{1\,ft}{12\,\cancel{in}} = 0.66667\,ft \qquad V = (12\,ft)(6\,ft)(0.66667\,ft)(7.48\,gal/ft^3)$$
$$= \boxed{359.04\,gal}$$

10. Calculate the maximum volume of water (in gallons) for a kids' swimming pool that measures 6 feet across and can hold 18 inches of water.

$$\frac{18\,\cancel{in}}{} \Big| \frac{1\,ft}{12\,\cancel{in}} = 1.5\,ft \qquad Vol. = (0.785)(D)^2(\text{depth})$$
$$= (0.785)(6\,ft)^2(1.5\,ft)(7.48\,gal/ft^3)$$
$$= \boxed{317\,gal}$$

11. How much water (in gallons) can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

$$V = (0.785)(3.5\,ft)^2(4\,ft)(7.48\,gal/ft^3)$$
$$= \boxed{287.7\,gal}$$

Area and Volume

Section 2

12. A water main has just been laid and needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

$\frac{30\,\text{in}}{} \Big| \frac{1\,\text{ft}}{12\,\text{in}} = 2.5\,\text{ft}$

$\frac{0.25\,\text{mi}}{} \Big| \frac{5280\,\text{ft}}{1\,\text{mi}} = 1320\,\text{ft}$

$V = (0.785)(2.5\,\text{ft})^2(1320\,\text{ft})(7.48\,\text{gal/ft}^3)$

$= \boxed{48{,}442\ \text{gal}}$

13. A water main is 10" in diameter and has a length of 5,000 feet. How many million gallons of water will it hold?

$\frac{10\,\text{in}}{} \Big| \frac{1\,\text{ft}}{12\,\text{in}} = 0.8333\,\text{ft}$

$V = (0.785)(0.8333\,\text{ft})^2(5{,}000\,\text{ft})(7.48\,\text{gal/ft}^3)$

$= 20388\ \text{gal} = \boxed{0.02\ \text{MG}}$

14. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to figure 5% of the tank volume. How many gallons will this be?

5% of $3\,\text{MG} \Rightarrow (0.05)(3\,\text{MG}) = 0.15\,\text{MG}$

$= \boxed{150{,}000\ \text{gal}}$

15. What is 5% of a 1.2 MG tank?

$(0.05)(1.2\,\text{MG}) = \boxed{0.06\,\text{MG or } 60{,}000\,\text{gal}}$

CONVERSIONS

16. How many seconds in 1 minute? 60 sec/min

17. How many minutes in 1 hour? 60 min|hr

18. How many hours in 1 day? 24 hr/d

19. How many minutes in 1 day? 1440 min/d

Area and Volume

20. The flow through a pipe is 3.6 cfs. What is the flow in gps?

$$\frac{3.6\,\cancel{ft^3}}{sec}\left|\frac{7.48\,gal}{1\,\cancel{ft^3}}\right. = 26.9 \text{ gps}$$

21. The flow through a pipe is 2.4 cfs. What is the flow in gpm?

$$\frac{2.4\,\cancel{ft^3}}{\cancel{sec}}\left|\frac{7.48\,gal}{1\,\cancel{ft^3}}\right|\frac{60\,\cancel{sec}}{1\,min} = 1077 \text{ gpm}$$

22. A pump produces 22 gpm. How many cubic feet per hour is that?

$$\frac{22\,\cancel{gal}}{\cancel{min}}\left|\frac{1\,ft^3}{7.48\,\cancel{gal}}\right|\frac{60\,\cancel{min}}{1\,hr} = 176.5 \text{ ft}^3/\text{hr}$$

23. A treatment plant produces a flow of 6.31 MGD. What is the flow in gpm?

$$\frac{6.31\,\cancel{MG}}{1\,\cancel{D}}\left|\frac{1{,}000{,}000\,gal}{1\,\cancel{MG}}\right|\frac{1\,\cancel{D}}{1440\,min} = 4382 \text{ gpm}$$

24. A pump produces 700 gpm. How many MGD will the pump flow?

$$\frac{700\,\cancel{gal}}{\cancel{min}}\left|\frac{1\,MG}{1{,}000{,}000\,\cancel{gal}}\right|\frac{1440\,\cancel{min}}{1\,D} = 1.008 \text{ MGD}$$

25. A three-eights mile segment of pipeline is to be repaired. How many feet of pipeline is this?

$3/8 = 0.375$

$$\frac{0.375\,\cancel{mile}}{}\left|\frac{5280\,ft}{1\,\cancel{mile}}\right. = 1980 \text{ ft}$$

26. If there is a 2,200 gallon tank full of water, how many pounds of water is in the tank?

$$\frac{2{,}200\,\cancel{gal}}{}\left|\frac{8.34\,lbs}{1\,\cancel{gal}}\right. = 18{,}348 \text{ lbs}$$

Section 3

Applied Math for Distribution
Flow Conversions

1. **Express a flow of 5 cfs in terms of gpm.**

$$\frac{5\ \cancel{ft^3}}{\cancel{sec}} \left| \frac{7.48\ gal}{1\ \cancel{ft^3}} \right| \frac{60\ \cancel{sec}}{1\ min} = \boxed{2244\ gpm}$$

2. **What is 38 gps expressed as gpd?**

$$\frac{38\ gal}{\cancel{sec}} \left| \frac{60\ \cancel{sec}}{1\ \cancel{min}} \right| \frac{1440\ \cancel{min}}{1\ d} = \boxed{3,283,200\ gpd}$$

3. **Convert a flow of 4,270,000 gpd to cfm.**

$$\frac{4,270,000\ \cancel{gal}}{\cancel{day}} \left| \frac{1\ ft^3}{7.48\ \cancel{gal}} \right| \frac{1\ \cancel{d}}{1440\ min} = \boxed{396\ ft^3/min}$$

4. **What is 5.6 MGD expressed as cfs? (round to nearest tenth)**

$$\frac{5.6\ \cancel{MG}}{\cancel{D}} \left| \frac{1,000,000\ \cancel{gal}}{1\ \cancel{MG}} \right| \frac{1\ ft^3}{7.48\ \cancel{gal}} \left| \frac{1\ \cancel{d}}{1440\ \cancel{min}} \right| \frac{1\ \cancel{min}}{60\ sec} = \boxed{8.7\ ft^3/sec}$$

5. **Express 423,690 cfd as gpm.**

$$\frac{423,690\ \cancel{ft^3}}{\cancel{d}} \left| \frac{7.48\ gal}{1\ \cancel{ft^3}} \right| \frac{1\ \cancel{d}}{1440\ min} = \boxed{2201\ gpm}$$

6. **Convert 2730 gpm to gpd.**

$$\frac{2730\ gal}{\cancel{min}} \left| \frac{1440\ \cancel{min}}{d} \right. = \boxed{3,931,200\ gal/d}$$

Applied Math for Collections
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

$$\text{Vel.} = \frac{\text{distance, ft}}{\text{time}} = \frac{370 \text{ ft}}{2 \text{ min}} = \boxed{185 \text{ ft/min}}$$

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec? 2 min + 14 sec = 134 seconds total

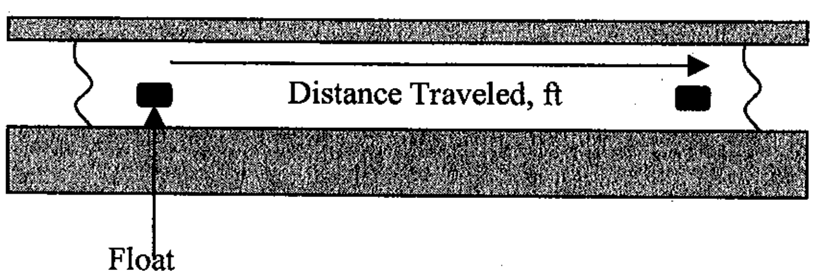
means we need time in seconds!!

$$\text{Vel} = \frac{300 \text{ ft}}{134 \text{ sec}} = \boxed{2.2 \text{ ft/sec}}$$

3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min? 30 sec = 0.5 min

need time in minutes

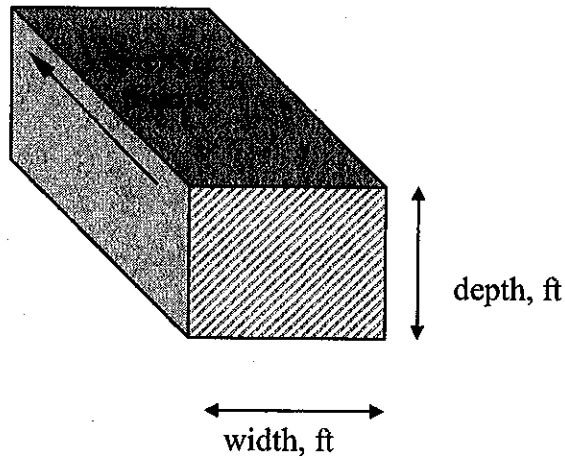
$$\text{Vel} = \frac{105 \text{ ft}}{0.5 \text{ min}} = \boxed{210 \text{ ft/min}}$$



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$

Section 3



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

w = 48 in = 4 ft
d = 1.5 ft
vel = 2.8 ft/sec

$Q = (w)(d)(vel)$
$= (4 ft)(1.5 ft)(2.8 ft/sec)$
$= \boxed{16.8 \ ft^3/sec}$

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

w = 3 ft
d = 2.5 ft
vel = 120 ft/min

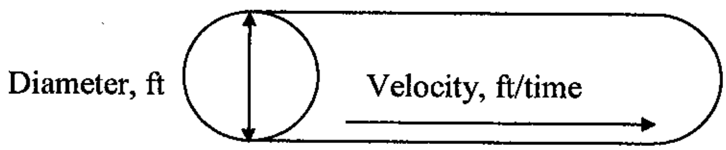
$Q = (3 ft)(2.5 ft)(120 ft/min) = \boxed{900 \ ft^3/min}$

$\frac{(900 ft^3/min)(1440)(7.48)}{1,000,000} = \boxed{9.69 \ MGD}$

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft³/sec, what is the depth of the water in the channel in feet?

w = 3 ft
vel = 1.5 ft/sec
Q = 8.1 ft³/sec

$Q = (w)(d)(vel)$
$\underset{ft^3/sec}{8.1} = \underset{ft}{(3)}\underset{ft}{(d)}\underset{ft/sec}{(1.5)}$
$8.1 = (4.5)(d)$
$\frac{8.1}{4.5} = d$
$\boxed{1.8 = d \ ft}$



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\underset{(ft)(ft)}{(D)^2} \quad \underset{(ft/time)}{(vel)}$$

<u>Flow through full pipe</u>

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

D = 2 ft
vel = 3.2 ft/sec

$Q = (0.785)(D,ft)(D,ft)(vel)$
$= (0.785)(2ft)(2ft)(3.2 ft/sec)$
$= \boxed{10\ ft^3/sec}$

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

D = 6 in = 0.5 ft
vel = 3 ft/sec

$Q = (0.785)(0.5ft)(0.5ft)(3 ft/sec)$
$= \boxed{0.59\ ft^3/sec}$

9. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

D = 8 in = 0.6667 ft
vel = 3.4 ft/sec

$Q = (0.785)(0.6667 ft)(0.6667 ft)(3.4 ft/sec)$
$= (1.1862\ ft^3/sec)(60)(7.48) = \boxed{532\ gpm}$

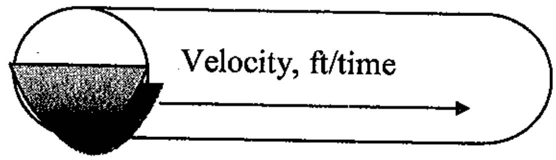
10. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

Q = 0.7 ft^3/sec
vel = 3.6 ft/sec

$Q = (0.785)(D,ft)(D,ft)(vel)$
$0.7 = (0.785)(D^2)(3.6)$
$0.7 = (2.826)(D^2)$
$\frac{0.7}{2.826} = D^2$
$\sqrt{0.25} = D^2$

0.50 = D
ft not inches
$\boxed{6 in}$ = 0.5 ft

Section 3



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = \overbrace{(\text{Factor from d/D Table}) \underset{(ft)(ft)}{(D)^2} \quad \underset{(ft/time)}{(\text{vel})}}$$

<u>Flow through pipe flowing less than full</u>

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

D = 12 in = 1 ft
d = 6 in
vel = 300 ft/min

Q = (0.3927)(1 ft)(1 ft)(300 ft/min)
= (117.81 ft³/min)(7.48) = $\boxed{881 \text{ gpm}}$

d/D = 6/12 = 0.5 ⟶ 0.3927 on chart

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

D = 10 in = 0.8333 ft
d = 5 in
vel = 3.2 ft/sec

Q = (0.3927)(0.8333 ft)(0.8333 ft)(3.2 ft/sec)
= (0.8727 ft³/sec)(60)(1440)(7.48)
= $\boxed{563{,}980 \text{ gpd}}$

d/D = 5/10 = 0.5 ⟶ 0.3927 on chart

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm? ~ min – means flow needs to be in ft³/min

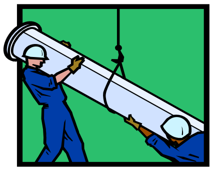
D = 8 in = 0.6667 ft
d = 5 in
Q = $\frac{415.85 \text{ gpm}}{7.48}$ = 55.5949 ft³/min

d/D = 5/8 = 0.625 ≈ 0.63 ⟶ 0.5212 on chart

Q = (d/D number)(D, ft)(D, ft)(vel)
55.5949 ft³/min = (0.5212)(0.6667 ft)(0.6667 ft)(vel)
55.5949 = (0.2316)(vel)
$\frac{55.5949}{0.2316}$ = vel
$\boxed{240 \text{ ft/min} = \text{vel}}$

Section 4

Pipe Installation



PIPE INSTALLATION AND MAINTENANCE

TDEC – Fleming Training Center 1

Pipe Shipping and Unloading

- Can be shipped via truck, railroad or barge
- Pipe should be inspected upon arrival
- Handle carefully
- Inspect lining and coating

TDEC – Fleming Training Center 2

Pipe Shipping and Unloading

- Plastic pipe inspected closely if arriving in cold weather
- Use proper equipment to unload

The short laying lengths of pre-insulated PVC sewer pipe permit site handling with conventional equipment.

TDEC – Fleming Training Center 3

Stacking Pipe

- If pipe is to be stacked and stored - ensure it is stored off the ground
- Secure pipe to prevent rolling
- Secure the storage area
- Protect plastic pipe from sunlight - but allow air circulation

TDEC – Fleming Training Center 4

Stringing Pipe

- Lay pipe as near to the trench as possible to minimize handling
- String pipe on side opposite of spoil pile
- Place bells in direction of installation
- Secure each section to prevent rolling into trench
- String only enough for one days work to prevent vandalism
- May need to cover ends to keep dirt out and prevent contamination

TDEC – Fleming Training Center 5

Excavation

- Plans are prepared by project engineer and submitted for State approval
- Plans should show location and depth of line, manholes, etc.
- Plans should show location and depth of water and gas pipes, buried telephone lines, electric and cable lines
- Ensure selection of proper sized excavation equipment

TDEC – Fleming Training Center 6

Excavation

- Water and Sewer lines separation at least 18 inches between the bottom of the water main and top of the sewer line
- Sewers should be at least 10 feet horizontally from any water line
- Notify the public about the work

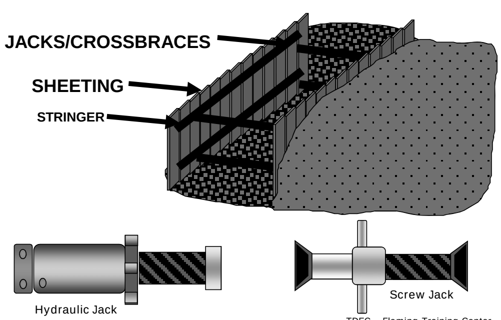
TDEC – Fleming Training Center 7

Trenching

- Most expensive part of pipe installation
- Minimize width and depth as much as possible without compromising safety
- Width should be no more than 1-2 feet more than pipe diameter, wider around curves
- Trench depth depends on maximum depth of frost penetration, minimum of 2.5 feet
- Minimum distance from trench to spoil pile is 2 feet

TDEC – Fleming Training Center 8

Shoring



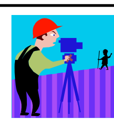
TDEC – Fleming Training Center 9

Trench Shields

- Shield systems must project at least 18 inches above the lowest point where the excavation face begins to slope

TDEC – Fleming Training Center 10

Trenching



- Must have a egress if 4 feet or deeper - stairway, ladders, etc
- Trench must be shored or sloped at 5 feet or deeper
- If 20 feet or deeper must be designed by an engineer
- Left open as short a time as possible
- Mark with barricades, warning tape, lights, etc to prevent accidents

TDEC – Fleming Training Center 11

Pipe Laying Procedures

- Inspect before laying and placing in trench
- Check for damage to the spigot end and lining
- Keep gaskets clean and dry

FIG. 19

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Pipe Laying Procedures

- Use a sling or pipe tong to place into trench-never roll
- Cover pipe with plug at the end of each work day
- Ensure pipe bedding is level and compacted
- Compact the backfill beneath the pipe curvature (Haunching)

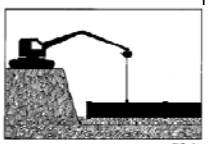

FIG. 21

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Pipe Joints

- Ensure gasket and spigot clean before being attached
- Bell holes or recesses in bedding dug to allow for joint installation
- Spigot end must be inserted to the painted line
- Full-length pipes are beveled at end to facilitate connection
- Level pipe for cutting
- Insert pipe straight

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Thrust Restraints In Pipe Installation

- Water under pressure and water in motion exerts tremendous pressure inside a pipeline
- All tees and bends should be restrained or blocked
- Thrust blocks are made of concrete or other permanent material
- Cast in place between fittings and undisturbed soil in the trench

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Thrust Restraints In Pipe Installation

- Thrust anchors can be used when there is no undisturbed solid to block against
- Tie rods are used to restrain mechanical joint fittings
- Steel rods hold the pipe and are attached to a block of concrete
- Restraining fittings use clamps and anchor screws

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Purpose Of Backfilling

- Provide for pipe and fitting support
- Provides lateral stability between pipe and trench walls
- Carries and transfers surface loads

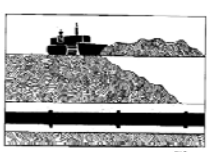

FIG. 24

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Placing Backfill

- Only clean sand or selected soil should be used for first layer
- Moist enough for compaction
- Should not contain peat, rocks, debris or frozen material

HDPE pipe installation

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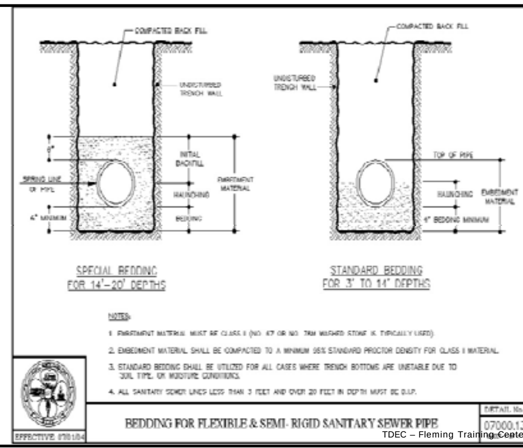
Placing Backfill

- First layer placed equally on both sides of pipe, up to center, and compacted
- Do by hand or pneumatic tamper
- Second layer should be good quality backfill material
- Remaining backfill can be excavated spoils



Compacting

- Trench backfill should be well compacted to avoid later settling
- Water compaction: jetting trench backfill with water
  - Not suitable for all soil types
  - Wide variation in results
  - Backfill must dry out before restoration or paving

Compacting

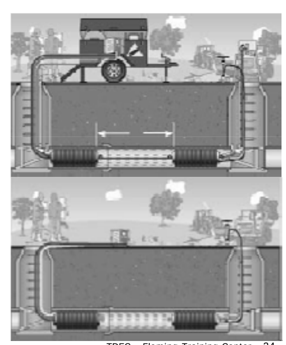
- Mechanical compaction: hand-held air tampers, plate vibrators, vibrating rollers
  - Excessive impact can damage pipe
  - Maintenance of shoring during compaction in lifts

Testing

- Air testing (air compressor):
  - Test sewer pipes at air pressure of 3-5 psi above any outside water pressure on pipe
  - Air test pressure too high can blow out pipe joints or plugs, can injure personnel, or damage system
  - Better in steep terrain because of excessive water pressure at lower end of sewer pipe

Low Pressure Air Testing

- Leak test accomplished by stringing the sewer line.
- Then, a winch cable pulls in 2 plugs which are attached with an interconnecting hose, through in 20 ft intervals.
- Air is fed between plugs until test fails.
- Leak is isolated by moving the plugs back and forth.



Water Testing

- Water exfiltration test indicates new sewer's ability to convey wastewater without excessive leakage & to resist groundwater infiltration
- Infiltration test: groundwater entering pipe is monitored through use of weir.
- Can't determine location of leak.

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Site Restoration

- Restored to original condition as soon as possible
- Grass restored, curbs replaced, pavement repaired
- Check drainage ditches for debris which would facilitate flooding
- Private property must be returned to original condition

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Safety

- Wear hard hats when necessary
- Follow safety guidelines including sloping and shoring
- Use proper traffic control measures, warning signs, traffic cones, tape off restricted and danger areas, caution lights
- Use proper precautions when unloading pipe
- Use proper Personal Protective Equipment (PPE)

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Section 5

Pipe Materials

Sewer Pipe Materials

Specification Standards

- Set by American Society of Testing Materials (ASTM) & American National Standards Institute (ANSI)
- Specify:
  - Internal diameter
  - Loadings (classes)
  - Wall thickness (schedule)

Selection Considerations

- Pipe materials are selected for their strength to withstand earth and surface loads and resistance to deterioration by the wastewaters they carry.
- Other considerations include resistance to root intrusion and costs of the materials and installation.
- Trench conditions
- Corrosion
- Temperature
- Safety requirements
- Cost

Key Pipe Characteristics

- Pipe must be resistant to corrosion from WW and surrounding soil
- Leak tightness: resistance to root intrusion and minimize infiltration and exfiltration
- Scouring factor
- Hydraulic characteristics

Pipe Materials

- Rigid Pipe
  - Asbestos-Cement Pipe
  - Cast-Iron Pipe
  - Concrete Pipe
  - Vitrified Clay Pipe
- Flexible Pipe
  - Ductile Iron Pipe
  - Steel Pipe
  - Thermoplastic Pipe
    - Acrylonitrile Butadiene Styrene
    - Acrylonitrile Butadiene Styrene Composite Pipe
    - Polyethylene Pipe
    - Polyvinyl Chloride Pipe

Asbestos-Cement Pipe (AC)

- No longer manufactured
- It was used frequently for gravity and pressure sewers from 4 - 42 in
- Still found in many sanitary sewer systems throughout the US

Asbestos-Cement Pipe

- Advantages
  - Long laying lengths
  - Availability of a wide range of strength classifications
  - Availability of a wide range of fittings
  - Resistant to abrasion
- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to shear and beam breakage when improperly bedded
  - Low beam strength
  - Restrictions by OSHA due to asbestos content (precautions need to be taken when repairing AC pipe)

Cast-Iron Pipe (CIP)

- CIP (gray iron) is used for both gravity and pressure sewers in diameters from 2 – 48 inches
- A cement mortar lining with an asphaltic seal coating may be specified on the interior of the pipe
- Very resistant to crushing and is often used for creek and river crossings, shallow trench locations, and under heavy traffic load areas

Cast-Iron Pipe

- Advantages
  - Long laying lengths (in some situations)
  - High pressure and load bearing capacity
- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to chemical attack in corrosive soils
  - Subject to shear and beam breakage when improperly bedded
  - High weight
  - High cost

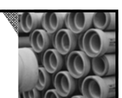
Concrete Pipe

- Reinforced (RCP) and non-reinforced concrete pipe are used for gravity sanitary sewers
- Reinforced concrete pressure pipe and prestressed concrete pressure pipe (PCPP) are used for pressure as well as gravity flow sanitary sewers
- Rigid; heavy
- Rubber gasket joints

Concrete Pipe

- Advantages
  - Wide range of structural and pressure strengths
  - Wide range of nominal diameters
    - 12-200 inches
  - Wide range of laying lengths
- Disadvantages
  - High weight
  - Subject to corrosion where acids are present (if not coated)
  - Subject to shear and beam breakage when improperly bedded
  - Special field repair methods and special fittings may be required for PCPP

Vitrified Clay Pipe



- Used for gravity sewers with laying lengths of 4-10 ft
- Manufactured from clay and shales
- Made non-porous (vitrified) by heating it at a high enough temperature to fuse the clay mineral particles
- 3-36 inch diameters are available, up to 42 in some areas
- Rigid
- Compression jointed
- Brittle: requires careful installation (shear & beam breakage possible)
- Heat resistant

Vitrified Clay Pipe

- Advantages
  - High resistance to chemical corrosion
  - High resistance to abrasion
  - Wide range of fittings available
- Disadvantages
  - Joints susceptible to chemical attack
  - Limited range of sizes available
  - High weight
  - Subject to shear and beam breakage when improperly bedded

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Ductile Iron Pipe (DIP)

- Rigid / Ductility: ability to slightly deform without cracking
- Used for both gravity and pressure sewers
- DIP is manufactured by adding cerium or magnesium to cast (gray) iron just prior to the pipe casting process
- 3-54 inch diameters and length of 20 ft avaialble
- Often used for stream crossings, inverted siphons and in high traffic area.
- Polyethylene, epoxy or cement mortar lining
- Outgrowth of cast iron industry in 1940's.

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Ductile Iron Pipe

- Advantages
  - Long laying lengths (in some situations)
  - High pressure and load bearing capacity
  - High impact strength
  - High beam strength
- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to chemical attack in corrosive soils
  - High weight
  - Expensive

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Steel Pipe

- Rarely used for gravity sewers but common for force mains
- Usually has interior protective coatings or linings (polymeric, bituminous, asbestos)
- 8-120 inch diameters with lengths up to 40 feet

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Steel Pipe

- Advantages
  - Light weight
  - Long laying lengths (in some situations)
- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to chemical attack in corrosive soils
  - Subject to excessive deflection when improperly bedded
  - Subject to turbulence abrasion

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Acrylonitrile Butadiene Styrene

- Lightweight black plastic pipe
- Long laying lengths
- Rather brittle: subject to environmental stress cracking
- Subject to attack by some organics
- Susceptible to damage by sunlight
- Elastomeric seal gasket joints or solvent cemented joints

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HDPE Pipe

- High Density Polyethylene
- Flexible
- Inert-not subject to chemical attack
- Resists corrosion from hydrogen sulfide
- Easily handled
- Longer laying length vs. heavier pipe
  - Gives long-term maintenance advantage of fewer joints and fewer root intrusions
- Nonporous
  - Although groundwater may infiltrate through poorly made joints or taps, but it won't seep through the walls
- Commonly used with pipe bursting & sliplining

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Polyvinyl Chloride (PVC)

- Most widely used plastic pipe
- Somewhat flexible
- Non-pourous
- Inert-not subject to chemical attack
- Easily handled, lighter weight vs rigid pipe
- Longer laying length vs. heavier pipe (10-20 ft)
- Must be well bedded Maximum Standard Dimension Ratio (SDR) of 35

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Polyvinyl Chloride (PVC)

- Needs to be protected from freezing temperatures and sunlight until installed
- Least susceptible to corrosion by acids formed from gases generated in sewers

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Section 6

Lift Stations

Wastewater Lift Stations

1


White House UD Pumping Station

PURPOSE
TYPES
COMPONENTS
OPERATION
SAFETY

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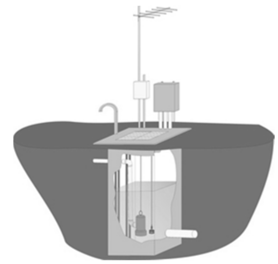
Purpose of Lift Stations

2

- Lift or raise wastewater or storm water from a lower to a higher elevation



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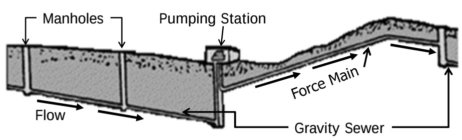
Location

3

- Excavation costs to keep gravity flow become excessive
- Poor soil stability
  - If soil is too unstable for trenching, pump station may be necessary.
- Groundwater table too high to install deep sewers
- Present flow insufficient to justify extension of large trunk sewers



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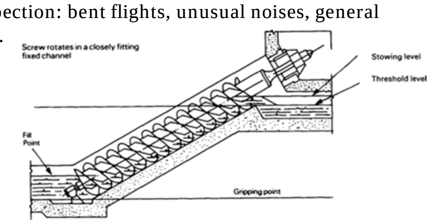
Screw Pumps

4

- Screw carries wastewater up to discharge point.
- Handle large solids & rags without clogging.
- Screw supported by 2 bearings-must lubricate.
- Daily inspection: bent flights, unusual noises, general operation.



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Screw Pumps

5

- Archimedes screw pumps at Memphis STP.
- Each is 8 feet in diameter and can lift 19,900 gpm (28.6 MGD).
- May be covered to control flies, odors and spread of wastewater in air.

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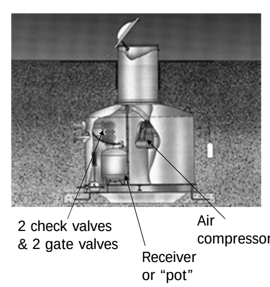
Pneumatic Ejector

6

- Uses compressed air to eject wastewater.
- Handles low flows with low to medium heads with large solids.
- Maintenance: clean grease from tank; inspect valves, air lines, & electrical controls.
- During routine maintenance, observe several cycles of the ejector.



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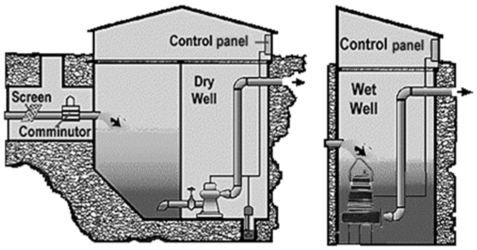
Installations

7

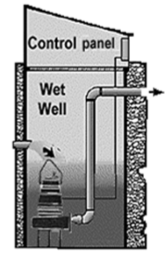
- Wet well/dry well vs. submersible pump station



Submersible Pump Station

8

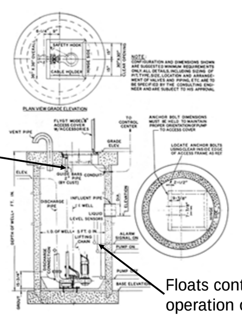
- Pump is in wet well
- Low flows & higher heads (pumping against a large change in elevation)



Submersible Pumping Station

9

- Pump-motor unit, electrical & mechanical controls, piping, wet well, access frame & cover
- Guide bars of 2" pipe allow removal of pump from top of the manhole.
- Check & isolation valves & flow meter installed in separate valve pit.
- Operator does not have to enter the wet well to remove or install the pump.

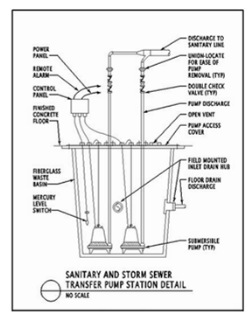


Floats control operation of pumps

Duplex Submersible Pumping Station

10

- Two pumps (duplex)
- Completely submerged in WW
- Waterproof motor
- Second pump provides continuous operation if 1 pump fails or needs repairs.
- When mechanical seal starts leaking, WW can enter the motor and cause motor to burn out
- Mechanical seals keep wastewater out
  - Check motor with megger monthly
  - Replace mechanical seals regularly
  - Clean grit out of wet well regularly

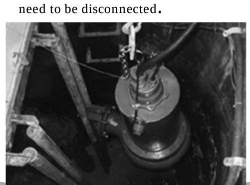


Submersible Lift Stations

11

- Submersible lift stations are designed to blend readily with natural surroundings, since there is no pump house and there is a minimum of above-ground equipment.
- Other advantages to below-ground installations are noise reductions and less safety-hazard concerns.

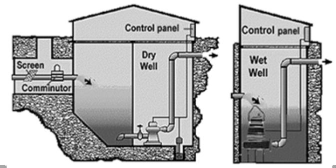
- This submersible wastewater pump is being lowered into a lift station on a guide rail system.
- All that is needed is a hoist; there is no need for a person to go into the pit.
- By using a guide rail system, pump maintenance and installation is easier because the piping system does not need to be disconnected.



Wet Well/Dry Well

12

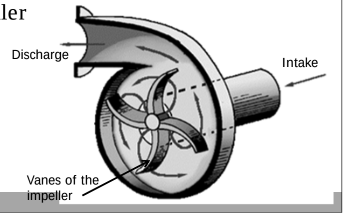
- Dry well houses pumps, motors, electrical controls, & auxiliary equipment.
- Typically for higher flows because has higher initial cost.
- Equipment in wet well is minimized.



Centrifugal Pumps

13

- Most common wastewater lift station pump
- Impeller: rotating vanes pump wastewater; large opening prevent clogging
- Volute: spiral-shaped casing collects water discharged by impeller



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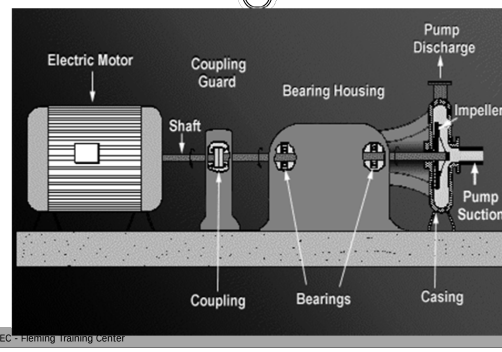
Horizontally Mounted Centrifugal Pump

14



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Pump Operation

15

- Frequent starts & stops:
  - Cause excessive motor wear
  - Cause surges in wastewater flow
  - Increase power costs
- Draw more power starting than during normal operation because motor & pump have to start turning

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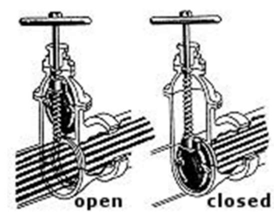
Gate Valves

16

- Needed in lift station to permit proper flow of wastewater and permit maintenance to occur
- Immediately before & after pump to isolate it from wet well & force main
- Operate inactive valves to prevent sticking
- Always "back off" half turn when fully opening or closing to avoid "freezing"



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Gate Valves

17

- More susceptible to plugging than plug valves
- Better than plug valves:
  - Some can be slammed shut by backflow, breaking the valve body & injuring operator from water hammer due to sudden stoppage of flowing water
  - Plug valves have a restriction which can become clogged with rags & sticks

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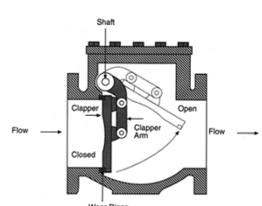
Check Valve

18



- Installed in discharge of each pump to prevent the force main from drawing back into the wet well.
- Swinging check valve has valve body with clapper arm that open when pump comes on & closes when pump shuts off.
- Must close before flow reverses to prevent water hammer

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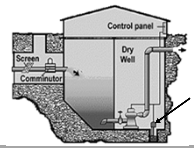
Auxiliary Equipment

19

- Screens & comminutors installed prior to pumps to prevent large debris from entering & plugging pipes.
  - Protects pumps downstream
- Sump pump in dry well removes accumulated moisture.
- Ventilation system with sensors & alarms.
- Lights sufficient in number & right location to avoid glare & shadows.



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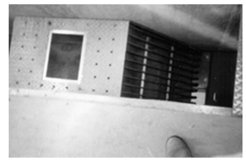
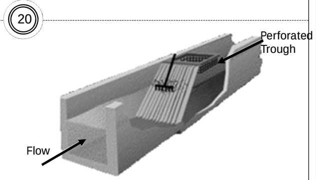
Manually Cleaned Bar Screen/Rack

20





- Bar screens or racks collect leaves, sticks, cans, and trash.
- Must be cleaned frequently so flow to the pumps is not restricted.
- Screenings can cause odors and attract rats and flies.
- Screening disposal in landfill.
- Safety
  - Be careful not to trip or fall into the wastewater.
  - Back injuries and muscle strains can occur when pulling heavy water-logged debris.

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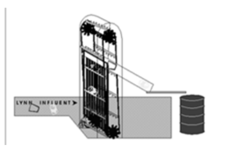
Mechanically Cleaned Bar Screen

21

- In larger installations, mechanically cleaned bar screens are installed.
- To reduce wear, controls clean the screen only when debris has accumulated and head loss reaches a preset level.
- Maintenance:
  - Keep well lubricated and adjusted
  - Hose down with water to prevent slime growth and odors/flies it generates



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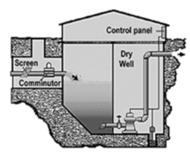
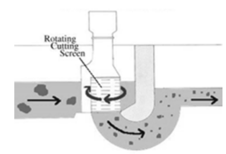
Comminutor

22





- Shreds solids, but leaves them in the wastewater.
- Safety: never attempt to unjam cutter blades without first bypassing unit, turning off power, locking out breaker & placing tag on breaker.
- Advantages vs. bar screens: eliminates screening disposal; eliminates problems from flies and odors.
- Disadvantages: plastic and wood may be rejected and must be removed manually.

Muffin Monster Video

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Level Controllers

23

- Float controllers:
  - Grease & debris can hinder movement
  - Float attachment line breakage
  - May develop leaks
  - Sensitive to level changes

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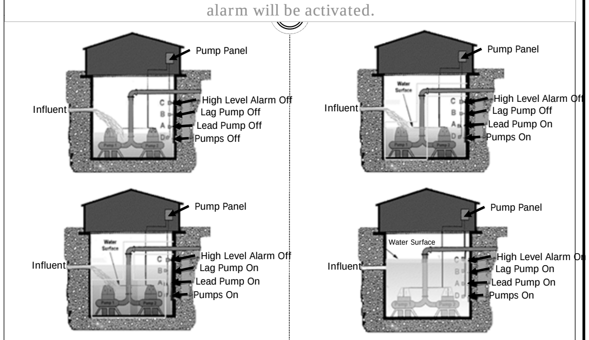
No pump will run until the water rises to level A or higher. As the water rises a pump will automatically turn on. If the water continues to rise, a 2nd pump will turn on. With both pumps running, if water level continues to rise, an alarm will be activated.



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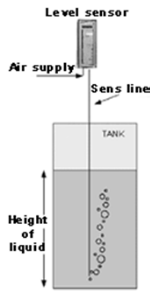
Level Controllers

25

- Air bubblers:
  - Constant low volume, low pressure air fed through vertically mounted pipe in wet well
  - Water level determined by force required to displace water in the pipe



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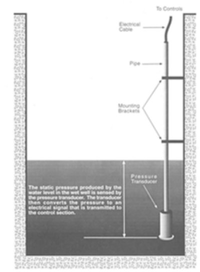
Level Controllers

26

- Pressure transducer:
  - Submerged
  - Pressure created by static head of water level sensed by flexible membrane.
  - Converted to electrical signal in control system.
  - Rags & debris foul unit
  - Grease may cover unit



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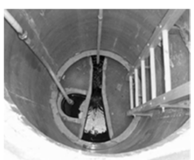
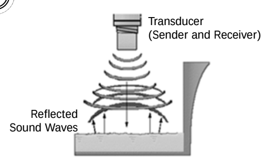
Level Controllers

27





- Ultrasonic transducer:
  - Ultrasonic pulses hit the water surface & bounce back.
  - Pulse travel time is converted to electrical signal in control system.

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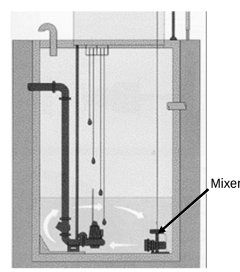
Grit

28

- Pump down the wet well to the lowest possible level and then flush the grit to the pump's suction with high pressure hoses.
- Grit accumulation leads to reduced flow to pumps and loss of wet well capacity.
- A mixer may re-suspended material in the bottom of the wet well.



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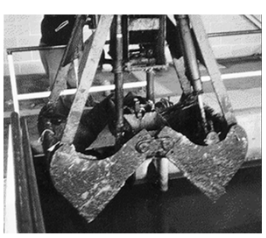
Grit Removal

29



- Removed by flushing, bucket machine or vacuum truck.

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Grease & Scum in Wet Well

30

- Causes odors & impairs functioning of equipment
- Removal:
  - Manual
  - Chemical/biological treatment of FOG

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Lift Station Problems

31

- Power
- Control system (flooded wet well)
- Pumping system (stuck check valve; air-bound pump)
- Structure (ventilation fan burned out)

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Lift Station Safety

32

- Confined space
- Hazardous atmospheres
- Slippery ladders or stairs
- Mechanical & electrical hazards
- Insects, snakes & rodents
- Infections & diseases
- Drowning

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Lift Stations Vocabulary

______1. Cavitation
______2. Comminutor
______3. Discharge Head
______4. Dry Well
______5. Entrain
______6. Force Main
______7. Head
______8. Impeller
______9. Lift Station
______10. Pneumatic Ejector
______11. Suction Head
______12. Volute
______13. Water Hammer
______14. Wet Well

A. A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.
B. A wastewater pumping station that lifts the wastewater to a higher elevation when continuing the sewer at reasonable slopes would involve excessive depths of trench. These stations may be equipped with air-operated ejectors or centrifugal pumps. Sometimes called a pump station.
C. A device used to reduce the size of the solids chunks in wastewater by shredding. The shredding action is like many scissors cutting to shreds all the large solids in the wastewater.
D. The spiral-shaped casing that surrounds a pump, blower or turbine impeller and collects the liquid or gas discharged by the impeller.
E. The vertical distance, height or energy of water above a point. This may be measured in either height (feet) or pressure (pounds per square in or psi).
F. A device for raising wastewater sludge or other liquid by compressed air.
G. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. It is accompanied by a loud noise that sounds like someone is pounding on the impeller or gate with a hammer.
H. The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system.
I. A rotating set of vanes in a pump designed to pump or lift water.
J. The pressure (in pounds per square inch or psi) measured at the centerline of a pump discharge and very close to the discharge flange, converted to feet. The pressure is measured from the centerline of the pump to the hydraulic grade line of the water in the discharge pipe.
K. The positive pressure (in feet or pounds per square inch or psi) on the suction side of a pump. The pressure can be measured from the centerline of the pump up to the elevation of the hydraulic grade line on the suction side of the pump.
L. To trap bubbles in water either mechanically through turbulence or chemically through a reaction.

M. Dry room or compartment in a lift station, near or below the water level, where the pumps are located.
N. Compartment or tank in which wastewater is collected.

Lift Stations Questions

1. What is the <u>purpose</u> of a lift station?

2. Why does a pump require more energy (draw more power) to start than it does during normal operating conditions?

3. What are the <u>advantages and limitations</u> of having bar racks/screens in wet wells?

4. Why should isolation valves in lift stations be gate valves instead of plug valves?

5. Why must lift stations have adequate ventilation?

6. What kind of problems or failures can occur in lift stations?

7. Why should air release valves be installed at high points in force mains?

8. Which type of pump is most commonly used in raw wastewater lift stations?

9. Why should lift stations be equipped with at least two pumps?

True-False

10. Equipment located in the wet well should be minimized.
    True
    False

11. Power to electrode controllers must be turned off and properly tagged before performing any maintenance on the equipment.
    True
    False

12. Gate valves are less susceptible to plugging than plug valves.
    True
    False

Multiple Choice

13. Lifting of wastewater in a lift station is accomplished by:
    a. Air lift pumps
    b. Centrifugal pumps
    c. Piston pumps
    d. Turbine pumps

14. Accumulated air in force mains is blown off by:
    a. Air release valves
    b. Altitude control valves
    c. Blowers
    d. Check valves

15. A sump pump is used to pump drainage out of a:
    a. Dry well sump
    b. Full wet well
    c. Manhole
    d. Wet well sump

16. The purpose of a check valve is to:
    a. Adjust the discharge flows from the pump
    b. Isolate the pump from the system
    c. Prevent the force main from draining back into the wet well
    d. Prevent plugging of pumps

17. Pumps draw more power starting than during normal operating conditions because:
    a. Gate valves have to be pushed open
    b. Pipe friction losses are greater
    c. The motor and pump have to start turning
    d. The total dynamic head is greater

18. <u>Advantages</u> of float control systems include:
    a. Capacity to completely drain the wet well
    b. May be reset manually or by remote control
    c. Sensitivity to water level changes
    d. Simple design eliminates fouling by grease or debris

19. <u>Limitations</u> of electrode controllers include:
    a. Grease or slime can cover electrodes
    b. If not properly maintained, pumps may not start and stop when desired
    c. Rags and debris can foul electrodes
    d. There are none
    e. A, B and C

Answers to Vocabulary and Questions

Vocabulary:

1. G
2. C
3. J
4. M
5. L
6. A
7. E
8. I
9. B
10. F
11. K
12. D
13. H
14. N

Questions:

1. To lift or raise wastewater or storm water from a lower elevation to a higher elevation
2. The energy required to start a pump is greater than the total dynamic head (TDH) during normal operating conditions because additional energy is required to start the motor and the pump to start the water flowing through the pipes, the check valves and the pump.
3. Advantages: Prevent any large debris from entering and plugging or damaging the pump. Limitations: Must be cleaned frequently so there is no substantial restriction of wastewater flow to the pumps.
4. Isolation valves in lift stations should be gate valves instead of plug valves because some types of plug valves can be slammed shut by wastewater backflow and possibly injure you and break the valves body or a portion of the pipe system from the water hammer due to the sudden stoppage of the flowing water. Also plug valves have a restriction that can be clogged with rags or sticks.
5. To provide a safe atmosphere for operation and maintenance operators
6. Power, control systems, pumping systems, structures
7. to prevent accumulation of air and other gases; trapped pockets of air reduce the carrying capacity of the pipe, increase pumping costs, contribute to damage by water hammer and may create negative pressures strong enough to collapse pipes
8. centrifugal pumps
9. to provide continuous operation if one pump fails or needs repairs
10. True
11. True
12. False
13. B
14. A
15. A
16. C
17. C
18. C
19. E

Section 7

Sewer Cleaning

High velocity cleaner with vacuum device to remove grit & debris

Flushing operation

PIPELINE CLEANING & MAINTENANCE

Purpose

2

- Operate and maintain collection system to function as intended
- Primary purpose is to maintain the capacity of the sewer
- Minimize the number of
  - Stoppages per mile
  - Odor complaints
  - Lift station failures

Stoppages

3

- Stoppages are caused by obstructions such as:
  - Roots
  - Debris
  - Grease
  - Broken pipe
  - Joint failure
  - Improper taps

Stoppages

4

- Debris found when removing stoppages includes:
  - Solidified grease
  - Detergents
  - Sticks
  - Rags
  - Plastic bags
  - Broken pipe
  - Brick
  - Rock
  - Sand
  - Silt
  - Egg shells

Factors Effecting Sewer Cleaning Methods

5

- Wastewater characteristics
- Fluctuations in flow
- Alignment or sewer grade
- Pipe materials
- Physical condition of sewer

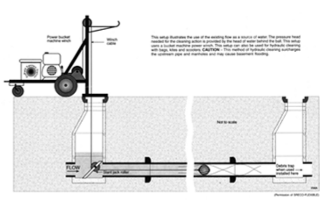
Solids

6

- Solids which settle out in sewers lead to
  - Corrosive conditions
  - Odors
  - Stoppages
  - Toxic hydrogen sulfide gas

Hydraulic Cleaning

7



- Water under pressure to produce high water velocities:
  - High velocity cleaner
  - Ball or kite
  - Scooter
  - Flushing

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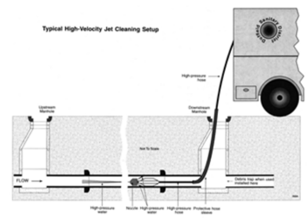
High Velocity Cleaner

8



- Effectively removes grease, sand, & debris
- Wash manholes and wet wells
- Effectiveness decreases as pipe diameter increases
- Preventive maintenance tool
- Water tank, high pressure water pump, pump power source, & hose reel

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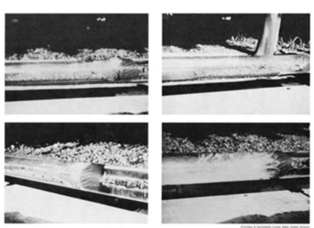
Cleaning with a Sewer Ball

9



- Preventive maintenance
- Spinning ball and high velocity water move debris downstream
- Effectively removes grease, sand, grit and other debris
- Don't use in areas with steep grade hills (basement flooding)
- Large sewers use kite, tire, or scooter instead of ball
- Cannot be use in areas with protruding taps or sewers with badly offset joints.

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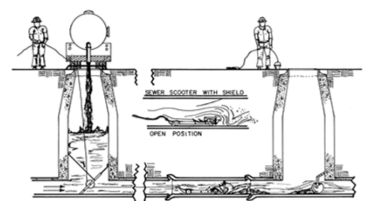
Sewer Scooter

10

- Effectively removes grease, grit, bricks, and rock by using water pressure
- Simple operation; inexpensive
- Tank truck, debris traps, control lines, control cable guide, power winch, scooter
- Depth of water in manhole is 3 times pipe diameter



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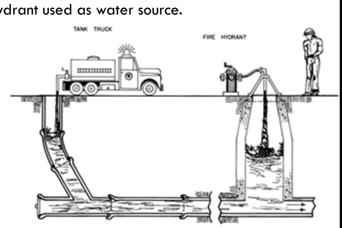
Flushing Operation

11

- May control odors at beginning of sewer where low flows may lead to solids accumulation.
- May also control insects and rodents in sewer.
- Also used with mechanical cleaning (bucket machines & power rodders).
- Air gap device needed if hydrant used as water source.
- Safety considerations:
  - Traffic
  - Atmosphere in manholes (toxic & explosive gases)
  - Avoid flooding of houses & businesses



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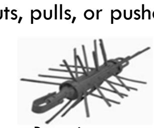
Mechanical Cleaning

12

- Uses equipment that scrapes, cuts, pulls, or pushes material out of pipe
  - Bucket machines
  - Power rodders
  - Hand rodders
  - Porcupines
  - Swabs



Porcupines are used to scour pipe walls of hardened debris, roots, & grease.

Swabs or poly pigs.

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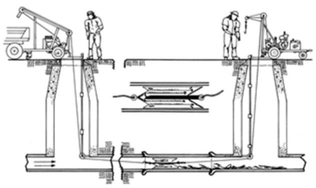
Power Bucket Cleaning

13



- Provides means to clean larger sewers
- Final cleanup using porcupine to scrub sewer line
- May require hydraulic cleaning afterwards to remove smaller debris (sand, grit)
- Working machine located at the upstream manhole when cleaning debris from large lines.
- Always pull porcupine downstream to avoid sealing off the line and causing the sewer to back up.

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Power Bucket Cleaning

14

- Power bucket machines are an excellent maintenance tool for removing large amounts of debris from the sewer, especially in large lines.
- In smaller sewers with lower flows, the working machine is usually located at the downstream manhole
  - Working from this manhole reduces the possibility of a stoppage developing in the sewer below the work area
- Often the working machine is located at the upstream manhole when clearing debris from larger lines

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Bucket Machine Maintenance

15

- Proper lubrication cable scroll and level wind system
- Inspect belt and chain tensions
- Inspect gear clearance
- Watch for frayed cable
- Watch for loose cable clamps

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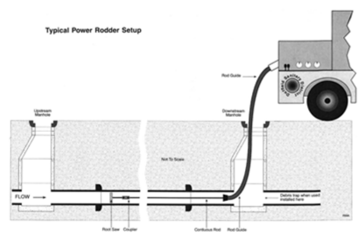
Power Rodder

16

- Effect removal for emergency stoppages
- Cuts roots & hardened grease



Auger (top) pilots hole through roots and grease then another tool such as root saw (bottom) can be used more easily.

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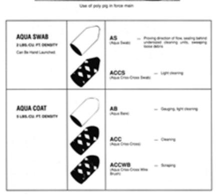
Poly Pig

17

- Polyurethane swab.
- Insert pig into pipeline then pressurize force main behind it.



Types of swabs and pigs.

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Cleaning Equipment Maintenance

18

- Keep equipment in good repair
- Help prevent equipment failure
- Prolong life of equipment
- Increase the efficiency and safety of maintenance operations

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High Velocity Cleaners

19

- Commonly used to perform routine cleaning (removal of sand, grit, light grease and small debris) of small to medium-sized collection system pipes
- During operation, be alert for:
  - Odd or suspicious noises
  - Higher or lower than usual rpm
  - Sluggish reel return
- If using during cold weather, drain the pump daily.

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Chemical Application

20

- Roots
- Grease
- Odors
- Concrete corrosion
- Rodents
- Insects

Application of rat poison in Paris

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Root Control

21

- Root intrusion over time leads to pipe breakage.
- Power rodders are most effective method to remove roots using root saw.
- Chemical root control agents applied by flooding or foaming retard root regrowth.

Root saw or cutter

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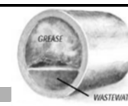
Grease



22

- Sources: restaurants, hospitals, industries and homes with garbage disposals
- Rate of buildup depends on amount in WW, flow, velocity, & sewer size
- Solutions: grease-eating bacteria, power rodders, high velocity cleaning (HVC)
- Inspect & clean grease traps as needed
  - Sewers > 18 in typically have fewer grease problems

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Odors

23

- Due to: low-velocity flows; long sewer lines; high temperatures; poorly maintained collection systems
- Masking agents
  - Overpower the odor
  - Do not correct the problem
- Most common sewer odor is hydrogen sulfide

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Why Control Hydrogen Sulfide?

24

- Toxic
- Can cause corrosion
- Flammable and explosive
- Colorless
- Rotten egg odor
- Loss of sewer capacity

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Why Control Hydrogen Sulfide?

25

- Paralysis of respiratory system may lead to death of sewer workers.
- Produced under anaerobic conditions by bacteria in slime layer that convert sulfate to sulfide.
- Gas is released and other bacteria use it to produce sulfuric acid.
  - This leads to corrosion of sewers, structures & equipment.
- Corrosive to concrete, Fe, Cu, Zn, Pb, Cd.
- LEL (lower explosive limit) is 4.3% and UEL (upper explosive limit) is 45%.

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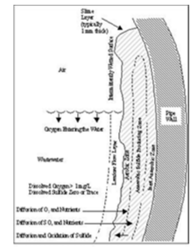
Factors that Contribute to Hydrogen Sulfide Production

26

- Sulfate concentration
- Concentration of organic matter
- pH
- Temperature
- Oxygen
  - Critical DO is 0.1 to 1.0 mg/L.
- Amount of slime on pipe walls
  - Sulfide production is faster at warmer WW temperatures.
- Lower stream velocity leads to thicker slime layer.



Anatomy of corrosive slime layer within a typical wastewater system pipe.

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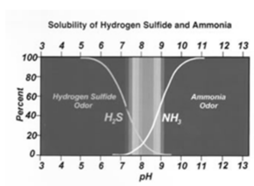
More on Hydrogen Sulfide

27

- Exposure for 2 min at 0.01% impairs sense of smell- *olfactory fatigue*
- Specific gravity 1.19
- Maximum safe 15-minute exposure: 20 ppm (OSHA)
- Greatest problem at wastewater pH <5



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Methods of Odor Control

28

- Aeration
  - Injection compressed air or venturi aspirator
  - Oxidizes existing sulfides in water
  - Prevents downstream sulfide formation (keeps water aerobic)
  - Cheapest chemical available- it's free
- Nitrate addition
  - Bioxide®
  - Bacteria use nitrate before sulfate in water

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Chemical Oxidation of Odors

29

- Chlorine (Cl_2, $Ca(OCl)_2$ or NaOCl)
  - Often at lift station (high turbulence)
  - Dose: 10-20 mg/L
  - Toxic to sulfide generating bacteria
- Hydrogen peroxide (H_2O_2)
  - Keeps WW aerobic; oxidizes H_2S
  - Dose:
    - 35% conc. 13-15 mg/L per mg/L H_2S
    - 50% conc. 11-13 mg/L per mg/L H_2S

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Other Chemicals for Odor Control

30

- Sodium hydroxide (NaOH)
  - Periodic treatment to inactivate bioslime
  - Increase pH to > 12.5 for 30 min
  - Safety considerations while handling
  - NaOH conc. is typically 3-6 %. Must be careful to not overfeed
- Iron salts
  - React with dissolved sulfide to form metal precipitate to prevent release of H_2S to air
  - Corrosive acid solution
    - Storage tanks for iron salts must be fiberglass or steel lined with rubber.
    - Pipes must be PVC.
    - Pumps must be plastic or rubber-lined to prevent corrosion

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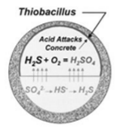
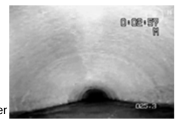
Other Chemicals for Odor Control

31

- Magnesium hydroxide (Thioguard®)
  - Raises WW pH>8, so sulfide is not produced
  - Binds up sulfide in solution forming magnesium polysulfide
  - Adds alkalinity
  - Non hazardous & environmentally safe
- Improves treatment plant performance:
  - Controls odors
  - Addition of alkalinity aids nitrification
  - Cationic-improves sludge settleability and removal of TSS and BOD



Magnesium hydroxide also sprayed on crown to stop corrosion.



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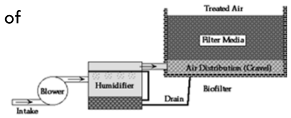
Other Methods of Odor Control

32

- Air is introduced into a bed of compost or peat (media).
- Bacteria living in media biologically oxidize odors.
- Other odors captured by media are chemically oxidized.



- Left: Biofilters can treat odors in air vented from sewer.
- Right: Manhole insert can treat odors at one manhole.

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Other Chemical Uses

33

- Herbicides, insecticides, fungicides, and rodenticides require registration by the US EPA Pesticides Regulation Commission.
- Before using any chemicals, field crew must read the label on the container & the MSDS.
- Never put chemicals with metal chips or filings into sewer since hydrogen gas may be produced.

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Questions

34

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Way Makers: Pipeline Cleaning and Chemical Control (39 min)

1. Power bucket machines are an excellent maintenance tool for removing large amounts of debris from the sewer, especially in ___________________ lines.

2. In smaller sewers with lower flows, the working machine is usually located at the ______________________ manhole. Working from this manhole reduces the possibility of a stoppage developing in the sewer below the work area.

3. Often the working machine is located at the _____________________ manhole when clearing debris from larger lines.

4. The sewer line can be cleaned with a _____________________ after a bucket has been pulled through the line.

5. NEVER use __________________ gloves while handling or guiding a rod that is turning.

6. Proper application of effective chemicals can be used to control _______________, grease, _____________, concrete corrosion, rodents, and __________________.

7. Before using any chemicals, make sure the field crew has thoroughly read the ________________ and the label on the chemical container.

8. All chemicals of the herbicide, insecticide, fungicide or rodenticide types require registration under the ______________ _______________.

9. NEVER put any chemicals containing metal chips or fillings into a sewer since it may produce _______________________ gas.

10. Treatment with sodium hydroxide consists of feeding enough into a sewer to raise the pH to almost _______________ for _____________ minutes.

1. Large	2. Downstream	3. Upstream
4. Porcupine	5. Rubber/latex	6. Roots, insects, odor
7. MSDS (SDS)	8. USEPA	9. Hydrogen
10. 13, 30		

Cleaning & Maintenance Vocabulary

______1. Air Gap
______2. BOD
______3. Balling
______4. Bucket
______5. Flushing
______6. High-Velocity Cleaner
______7. Hydraulic Cleaning
______8. Insecticide
______9. Kite
______10. Mechanical Cleaning
______11. Pesticide
______12. Porcupine
______13. Rod
______14. Rodenticide
______15. Scooter
______16. Sewer Ball
______17. Swab

A. A machine designed to remove grease and debris from the smaller diameter sewer pipes with high-velocity jets of water.
B. Clearing pipe by using equipment that scrapes, cuts, pulls or pushes the material out of the pipe. These include bucket machines, power rodders and hand rods.
C. A sewer cleaning tool the same diameter as the pipe being cleaned. The tool is a steel cylinder having solid ends with eyes cast in them where a cable can be attached and pulled by a winch. Many short pieces of cable or bristles protrude from the cylinder to form a round brush.
D. A method of hydraulically cleaning a sewer or storm drain by using the pressure of a water head to create a high cleansing velocity of water around the ball.
E. Any substance or chemical formulated to kill or control insects.
F. A sewer cleaning tool whose cleansing action depends on the development of high water velocity around the outside edge of a circular shield. The metal shield is rimmed with a rubber coating and is attached to a framework on wheels. The angle of the shield is controlled by a chain-spring system that regulates the head of water behind it and thus the cleansing velocity of the water flowing around the shield.
G. A special device designed to be pulled along a sewer for the removal of debris from the sewer. It has one end open with the opposite end having a set of jaws.
H. A spirally grooved, inflatable, semi-hard rubber ball designed for hydraulic cleaning of sewer pipes.
I. Any substance or chemical designed or formulated to kill or control animal pests.
J. A circular sewer cleaning tool almost the same diameter as the pipe being cleaned. As a final cleaning procedure after a sewer line has been cleaned with a porcupine, this is pulled through the sewer and the flushing action of water flowing around the tool cleans the line.
K. An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use. This gap prevents backsiphonage because there is no way wastewater can reach the drinking water.
L. Any substance or chemical used to kill or control rodents.

M. Cleaning pipe with water under enough pressure to produce high water velocities using: a high-velocity cleaner; a ball, kite or similar sewer cleaning device; a scooter; or flushing.
N. A device for hydraulically cleaning sewer lines. Resembling an airport windsock and constructed of canvas-type material, it increases the velocity of a flow at its outlet to wash debris ahead of it.
O. The removal of deposits of material that have lodged in sewers because of inadequately velocity of flows. Water is discharged into the sewers at such high rates that the larger flow and higher velocities are sufficient to remove the material.
P. A light metal rod, three to five feet long with a coupling at each end. They are joined and pushed into a sewer to dislodge obstructions.
Q. Biochemical Oxygen Demand. The rate that organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions.

Cleaning & Maintenance Questions

1. What are the <u>major</u> causes of stoppages?

2. What is the <u>most effective</u> method of removing grease buildups?

3. How can a stoppage caused by roots be cleared?

4. List three sewer line hydraulic cleaning methods.

5. What kinds of deposits in sewers can be removed by balling?

6. Where is the additional water obtained to provide the necessary head for a balling operation when flows in the sewer are low?

7. What are the uses of high-velocity cleaning machines?

8. Where should you start to clean the sewers in a given area or subdivision?

9. Which direction does the nozzle travel in the sewer?

10. Scooters can be used to remove what kinds of material from sewers?

11. How are force mains often cleaned?

12. Identify two sewer line mechanical clearing techniques.

13. What is the purpose of the porcupine tool?

14. Chemicals can be used to control what types of problems in wastewater collection systems?

15. What are the causes or sources of grease problems?

16. What problems are created by the presence of hydrogen sulfide?

17. What are the sources of hydrogen sulfide?

18. What are three potential methods of chemical control of sulfide?

Answers to Video, Vocabulary and Questions

Way Makers Video:

1. Large	5. Rubber/latex	9. Hydrogen
2. Downstream	6. Roots, insects, odors	10. 13; 30
3. Upstream	7. MSDS	
4. Porcupine	8. USEPA	

Vocabulary:

1. K	5. O	9. N	13. P	17. J
2. Q	6. A	10. B	14. L	
3. D	7. M	11. I	15. F	
4. G	8. E	12. C	16. H	

Questions:

1. Major causes of stoppages include obstructions such as roots, grease, debris, broken pipe or joint failures. Vandals, construction work, forces of nature and intersecting flows can also cause stoppages.
2. High-velocity cleaners are effective tools for removing grease buildups in sewers up to 15 inches in diameter. A parachute or bag may be a better method for larger diameter sewers.
3. A stoppage caused by roots can be cleared by either a power rodder or a hand rodder. A high-velocity cleaner is also effective with a special head and proper operation.
4. Balling, high-velocity cleaner, flushing, sewer scooter, kites, tires and poly pigs
5. Deposits of grit and grease
6. Fire hydrants or water truck
7. Open stoppages, remove grease, clean lines of debris and wash manholes and wet wells
8. Start at the top or highest point in the collection system.
9. Direct nozzle upstream
10. Large objects such as brick, sand, gravel and rocks
11. Poly pigs are frequently used
12. Bucket machines, power rodders and hand rods

13. Final cleanup since the bristles produce a scrubbing action.
14. Chemicals can be used to control roots, grease, odors, corrosion, rodents and insects.
15. Restaurants, industries and homes with garbage disposals
16. Paralysis of the respiratory center and death of operators; rotten egg odor; corrosion and possible collapse of sewers, structures and equipment; loss of capacity of the sewer
17. Hydrogen sulfide comes from the reduction of sulfate to sulfide by bacteria in the slimes on sewers under anaerobic conditions.
18. Chlorine compounds, hydrogen peroxide, iron salts, air, sodium hydroxide, magnesium hydroxide, nitrates.

Section 8

Inspection and Testing

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Inspection & Testing Collection Systems


Smoke Testing


CCTV Truck Setup

1

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Reasons for Inspecting & Testing

- Identify problem areas
- Evaluate seriousness of detected problem
- Locate position of problems
- Provide information to supervisors regarding problems


Manhole cover, Odense, Denmark

2

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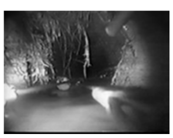
Why are Leaks a Problem?

- Infiltration uses valuable pipe and STP capacity
- Exfiltration could pollute soil, groundwater and surface water
- Root intrusion into sewers



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Major Problem Sources

- Design related deficiencies
- Improper installation
- Inadequate sewer use ordinances
- Improper inspection/enforcement taps or service connections
- Emergency situation (earthquake, explosion, etc.)
- Recurring problems
- Regional problems
- Old/neglected sewers

4

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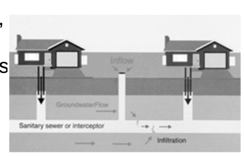
Why Control I/I?

- CS: leads to surcharged manholes, overflowing manholes, and exposure of community to diseases and pollutants carried by wastewater
- STP: can lead to plant loadings > capacity
  - Inadequate treatment
  - Bypasses (illegal)



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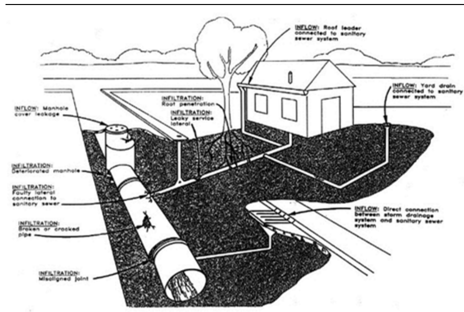
Sanitary Sewer Problems



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Infiltration

- Created by high levels groundwater
- Through deteriorated or broken pipes, joints, manholes
- Detected by metering flows during low flow periods
- Once located, conduct field verification using visual inspection, CCTV inspection and/or smoke or dye testing

7

Inflow

RainGuard Inflow Protector

- Enters from illegal connections or by drainage of flooded areas into CS
- Detection requires flow studies and inspections by smoke or dye testing
- Corrections require sewer use ordinance
- Storm water inflow from pick holes in cover, poor seal between cover & casting

8

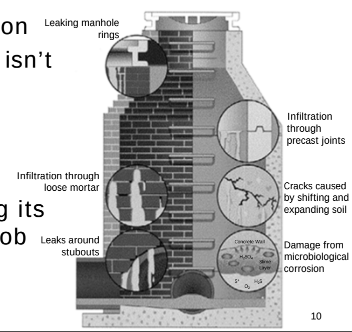
Exfiltration

- Leakage of wastewater out of CS through broken or damaged pipes or manholes
- May contaminate shallow wells or ditches where children and pets play
- Detected by CCTV inspection or smoke testing

9

Manhole Inspection: Objectives

- Lid elevation
- Ensure lid isn't buried
- Examine structural integrity
- Performing its intended job



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Manhole Inspection: Objectives

- Some agencies prohibit manhole steps and use ladders instead to eliminate hazards of corroded steps
- Manhole pressure tests are typically negative-pressure (vacuum) tests

11

Examining Manhole Surface

- Cracks or breaks
- Infiltration
- Joints
- Offsets
- Root intrusions
- Grease
- Gravel or debris
- Turbulence
- Grout bed of frame
- Shelf
- Flow
- Corrosion

12

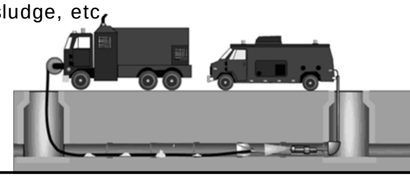
CCTV Inspections

- Inspect conditions and determine problem areas
- Look for damage due to paving, building construction, nearby utility work, etc.
- Positively ID sewer stoppages caused by roots
- Search for illegal taps
- Locate I/I sources and amounts
- Evaluate effectiveness of maintenance work
- Locate buried or lost manholes

13

CCTV Inspections

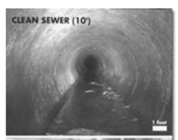
- "Pull type" CCTV inspection assembly requires at least two manholes be open.
- Pipe should be cleaned prior to inspection (high-velocity cleaning, power rodders, balling, bucket machines, water-jet vacuum trucks) to remove grit, grease, roots, sludge, etc.

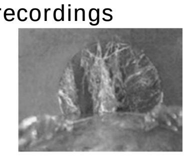


14

Logging & Recording CCTV Inspections

- Written log/inspection report
- Still photographs
- Videotape recordings





15

Logging & Recording CCTV Inspections

- Example of what camera may see:
  - CCTV inspection shows one section flowing ½ full, but upstream and downstream are only ¼ full, why?
  - There may be a sag in the pipe

16

CCTV Inspections

17

Purpose of Smoke Testing

- Sources of entry of surface water to CS
- Proof buildings are connected to CS
- Location of illegal or faulty connections
- Location broken sewers
- Location lost manholes

18

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Smoke Testing Equipment

- Smoke blower unit

- Pipe plugs

- Smoke bombs

19

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Preparations

- Warn public in advance when and where smoke testing is planned
- Involve local fire and police departments
- Train all operators how to handle persons who discover smoke in their homes
- Prepare operators to respect property and privacy of customers
- Inspect area to be tested

20

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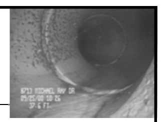
Dye Testing



- Used to:
  - Determine if facilities or fixtures are connected to sewer
  - Estimate velocity of WW in sewer
  - Test for infiltration and exfiltration
- Equipment: manhole hook & dye (tablet vs. powder)
- Start with downstream section and work upstream

21

Guardians of Health (Video #1)

O & M of Wastewater Collection Systems

33 minutes

1. List the 3 types of atmospheric hazards:
   a.
   b.
   c.
2. Existing manholes should be inspected every __________ to __________ years.
3. Smoke testing is used to determine:
   a. Sources of entry to collection system of surface waters including:
      i)
      ii)
      iii) Irrigation waters
   b. Location of illegal connections including:
      i)
      ii) Yard drains
      iii)
   c. Location of “lost” manholes and diversion points
4. Use of smoke for testing sewers is best done when the groundwater is __________.
5. List the 3 types of equipment needed for smoke testing operations:
   a.
   b.
   c.
6. Purpose of lamping:

Inspecting & Testing Vocabulary

______1. Corrosion
______2. Offset
______3. Pre-Cleaning
______4. Saddle Connection
______5. Sewer Gas
______6. Subsidence
______7. Surcharge
______8. Tag Line
______9. Water Table

A. A building service connection made to a sewer main with a device called a saddle.
B. A pipe joint that has lost its bedding support and one of the pipe sections has dropped or slipped, thus creating a condition where the pipes no longer line up properly.
C. A line, rope or cable that follows equipment through a sewer so that equipment can be pulled back out if it encounters an obstruction or becomes stuck. Equipment is pulled forward with a pull line.
D. The dropping or lowering of the ground surface as a result of removing excess water (overdraft or over pumping) from an aquifer. After excess water has been removed, the soil will settle, become compacted and the ground surface will drop and can cause the settling of underground utilities.
E. The gradual decomposition or destruction of a material due to chemical action, often due to an electrochemical reaction.
F. The upper surface of the zone of saturation of groundwater in an unconfined aquifer.
G. Gas in collection lines (sewers) that result from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.
H. Sewers are surcharged when the supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in the manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.
I. Sewer line cleaning, commonly done by high-velocity cleaners, that is done prior to the TV inspection of a pipeline to remove grease, slime and grit to allow for a clearer and more accurate identification of defects and problems.

Inspecting & Testing Questions

1. Why must inflow and infiltration be controlled?

2. What are the sources of inflow?

3. How can sources of infiltration be located?

4. How can infiltration problems be corrected or eliminated?

5. Why should exfiltration be controlled?

6. Why should manholes be inspected?

7. How often should a manhole be inspected?

8. Why must testing and inspecting collection systems be done thoroughly and on a regular basis?

9. Why should the TV camera always be pulled from the upstream manhole to the downstream manhole?

10. What is the purpose of smoke testing?

11. Where should observers look for smoke?

12. What is the purpose of dye testing?

13. What is the purpose of pipeline lamping?

Answers to Video, Vocabulary and Questions

Guardians of Health Video:
1. a. Explosive or flammable; b. Toxic; c. Oxygen deficient
2. 1-5years
3. a. i) Rain or storm water; ii) Street or surface wash water
   b. i) Roof leaders or down spouts, iii) Industrial drains
4. Low
5. a. Smoke blower unit; b. Pipe plugs; c. Smoke bombs
6. Establish that a section of pipe is straight and open or that it is not.

Vocabulary:

1. E	4. A	7. H
2. B	5. G	8. C
3. I	6. D	9. F

Questions:
1. Inflow and infiltration must be controlled to prevent hydraulic overload on the collection system or the wastewater treatment plant.
2. The source of inflow includes deliberate connections and surface drainage.
3. Sources of infiltration can be identified by the use of closed-circuit television, flow metering devices, smoke testing, dye testing and visual inspection.
4. Infiltration problems can be corrected or eliminated by sealing using pressure grouting, digging up and replacing pipe or inserting a plastic or fiber liner.
5. Exfiltration must be controlled because it can cause pollution of groundwaters.
6. Manholes should be inspected to be sure the lid is at the proper elevation, the manhole is structurally sound and the manhole is performing its intended job.
7. Every 1-5 years with those in heavy traffic areas being inspected more often.
8. To reduce the number of stoppages and failures.
9. The TV camera should always be pulled from the upstream manhole to the downstream manhole for the sake of consistency. Also there is a lesser chance of the camera becoming stuck in older lines. Pulling the camera toward the downstream manhole also helps to prevent a buildup of rages and debris in front of the lens.
10. To determine: sources of entry to the collection system of surface waters, proof that buildings or residences are connected to a wastewater collection system, location of illegal connections, location of broken sewers, location of lost manholes and diversion points.
11. Look for smoke from: roof vents, building foundations (especially where the house sewer passes under the foundation), yard drains, rain gutters and inside buildings.
12. To determine if certain facilities or fixtures are connected to the wastewater collection system, such as buildings that don’t show smoke from vents during smoke tests and yard drains or storm drains.
13. The purpose of pipeline lamping is to determine whether or not a section of pipe is straight and open.

Section 9

Rules and Regs

18 July 1995

THIS IS CHAPTER 2

CHAPTER 2

Sewers and Sewage Pump Stations

2.1 General Requirements for Collection Systems

2.2 Design Considerations

2.3 Design and Construction Details

2.4 Special Details

2.5 General Requirements for Sewage Pump Stations

2.5.1 Location and Flood Protection
2.5.2 Pumping Rate and Number of Units
2.5.3 Grit and Clogging Protection
2.5.4 Pumping Units
2.5.5 Flow Measurement
2.5.6 Alarm System
2.5.7 Emergency Overflow Pumping

2.6 Special Details

2.6.1 General
2.6.2 Wet Well - Dry Well Stations
2.6.3 Suction Lift Stations
2.6.4 Submersible Pumps
2.6.5 Pneumatic Ejectors
2.6.6 Grinder Pumps
2.6.7 Septic Tank Effluent Pump

2.7 Operability and Reliability

2.7.1 Objective
2.7.2 Backup Units
2.7.3 Emergency Power Supply (for Treatment Plants as well as pump stations)
2.7.4 Storage

2.8 Force Mains

2.8.1 Size
2.8.2 Velocity
2.8.3 Air Relief Valve
2.8.4 Termination
2.8.5 Materials of Construction
2.8.6 Pressure Tests
2.8.7 Anchorage
2.8.8 Friction Losses
2.8.9 Water Hammer

Appendix 2-A
Appendix 2-B
Appendix 2-C

SEWERS AND SEWAGE PUMP STATIONS

2.1 General Requirements for Collection Systems

2.1.1 Construction Approval

In general, construction of new sewer systems or extensions of existing systems will be allowed only if the downstream conveyance system and the receiving sewage treatment plant is either

a. Capable of adequately conveying or processing the added hydraulic and organic load, or

b. Capable of providing adequate conveyance or treatment facilities on a time schedule acceptable to the Department.

2.1.2 Ownership

Sewer systems including pumping stations will not be approved unless ownership and responsibility for operation are by a public entity or other acceptable long term operation or maintenance scheme is approved in advance by the Department.

2.1.3 Design

Sewer systems shall be designed and constructed to achieve total containment of sanitary wastes and maximum exclusion of infiltration and inflow. No combined sewers will be approved.

2.1.4 Emergency High Level Overflows

For use during possible periods of extensive power outages, mandatory power reductions, or uncontrollable emergency conditions, consideration should be given to providing a controlled, high-level overflow to supplement alarm systems and emergency power generation in order to prevent backup of sewage into basements, or other discharges which may cause severe adverse impacts on public interests, including public health and property damage. Where a high level overflow is utilized, consideration shall also be given to the installation of storage /detention tanks, or basins, which shall be made to drain to the station wet well where possible. All such constructed overflow structures must be telemetered to the control authority's headquarters where records must be maintained as to frequency and duration of the overflow.

2.1.5 Calculations

Computations and other data used for design of the sewer system shall be submitted to the Department. The Engineer shall utilize the format shown in Appendix 2-B or an approved equivalent.

2.1.6. SLOPE PROTECTION AND EROSION CONTROL

2.1.6.1 GENERAL

A. This Section shall consist of temporary control measures as shown in the Plans or directed by the Engineer during the life of the Contract to control erosion and pollution through the use of berms, dikes, dams, sediment basins, fiber mats, netting, mulches, grasses, slop drains, temporary silt fences, and other control devices.

B. The temporary pollution control provisions contained herein shall be coordinated with the permanent erosion control features, to assure economical, effective, and continuous erosion features, to assure economical, effective, and continuous erosion control throughout the construction and post-construction period.

2.1.6.2: MATERIALS

2.1.6.2.1 TEMPORARY BERMS

A. A temporary berm is constructed with compacted soil, with or without a shallow ditch, at the top of fill slopes or transverse to centerline on fills.

B. These berms are used temporarily at the top of newly constructed slopes to prevent excessive erosion until permanent controls are installed or slopes stabilized.

2.1.6.2.2 TEMPORARY SLOPE DRAINS: A temporary slope drain is a facility consisting of stone gutters, fiber mats, plastic sheets, concrete or asphalt gutters, half-round pipe, metal pipe, plastic pipe, sod or other material acceptable to the Engineer that may be used to carry water down slopes to reduce erosion.

2.1.6.2.3 SEDIMENT STRUCTURES: Sediment basins, ponds and traps, are prepared storage areas constructed to trap and store sediment from erodible areas in order to protect properties and stream channels below the constructed areas from excessive siltation.

2.1.6.2.4 CHECK DAMS

A. Check dams are barriers composed of logs and poles, large stones or other materials placed across a natural or constructed drain-way.

B. Stone check dams shall not be utilized where the drainage area exceeds fifty (50) acres. Log and pole structures shall not be used where the drainage area exceeds five (5) acres.

2.1.6.2.5 TEMPORARY SEEDING AND MULCHING

Temporary seeding and mulching are measures consisting of seeding, mulching, fertilizing and mating utilized to reduce erosion. All cut and fill slopes including waste sites and borrow pits shall be seeded when and where necessary to eliminate erosion.

2.1.6.2.6 BRUSH BARRIERS

A. Brush barriers shall consist of brush, tree trimmings, shrubs, plants, and other approved refuse from the clearing and grubbing operations.

B. Brush barriers are placed on natural ground at the bottom of fill slopes, where the most likely erodible areas are located to restrain sedimentation particles.

2.1.6.2.7 BALED HAY OR STRAW CHECKS

A. Baled hay or straw erosion checks are temporary measures to control erosion and prevent siltation. Bales shall be either hay or straw containing five (5) cubic feet or more of material.

B. Baled hay or straw checks shall be used where the existing ground slopes toward or away from the embankment along the toe of the slopes, in ditches or other areas where siltation erosion or water run-off is a problem.

2.1.6.2.8 TEMPORARY SILT FENCES Silt fences are temporary measures utilizing woven wire or other approved material attached to post with filter cloth composed of burlap, plastic filter fabric, etc., attached to the upstream side of the fence to retain the suspended silt particles in the run-off water.

2.1.6.3 EXECUTION

2.1.6.3.1 PROJECT REVIEW Prior to the pre-construction conference the Contractor shall meet with the Engineer and go over in detail the expected problem areas in regard to the erosion control work. Different solutions should be discussed so that the best method might be determined. It is the responsibility of the Contractor to develop an erosion control plan acceptable to the Engineer.

2.1.6.3.2 PRE-CONSTRUCTION CONFERENCE At the pre-construction conference the Contractor shall submit for acceptance his schedule for accomplishment of temporary and permanent erosion control work, as are applicable for clearing and grubbing, grading, bridges and other structures at water courses, construction and paving. He shall also submit for acceptance his proposed method for erosion control on haul roads and borrow pits and his plan for disposal of waste materials. No work shall be started until the erosion control schedules and methods of operations have been accepted by the Engineer.

2.1.6.3.3 CONSTRUCTION REQUIREMENTS

A. The Engineer has the authority to limit the surface area of erodible earth material exposed by clearing and grubbing, the surface of erodible earth material exposed by excavation, borrow and fill operations and to direct the Contractor to provide immediate permanent or temporary pollution control measures to prevent contamination of adjacent streams or other watercourses, lakes, ponds or other water impoundment. Such work may involve the construction of temporary berms, dikes, dams, sediment basins, slope drains and use of temporary mulches, mats, seeding or other control devices or methods to control erosion. Cut and fill slopes shall be seeded and mulched as the excavation proceeds to the extent directed by the Engineer.

B. The Contractor shall be required to incorporate all permanent erosion control features into the project at the earliest practicable time as outlined in his accepted schedule. Temporary pollution control measures shall be used to correct conditions that develop during construction that were not foreseen during the design stage; that are needed prior to installation of permanent pollution control features; or that are needed temporarily to control erosion that develops during normal construction practices, but are not associated with permanent control features on the project.

C. Where erosion is likely to be a problem, clearing and grubbing operations should be so schedule and performed that grading operations and permanent erosion control features can follow immediately thereafter if the project conditions permit; otherwise erosion control measures may be required between successive construction stages. Under no conditions shall the surface area of erodible earth material exposed at one time by clearing and grubbing exceed 750,000 square feet without approval of the Engineer.

D. The Engineer will limit the area of excavation, borrow and embankment operations in progress commensurate with the contractor's capability and progress in keeping the finish grading, mulching, seeding and other such permanent pollution control measures current in

accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion control measures shall be taken immediately to the extent feasible and justified.

E. Under no conditions shall the amount of surface area or erodible earth material exposed at one time by excavation or fill within the project area exceed 750,000 square feet without prior approval by the Engineer.

F. The Engineer may increase or decrease the amount of surface area of erodible earth material to be exposed at one time by clearing and grubbing, excavation, borrow and fill operations as determined by his analysis of project conditions.

G. In the event of conflict between these requirements and pollution control laws, rules or regulations, or other Federal, State or Local agencies, the more restrictive laws, rules or regulations shall apply.

2.1.7 SEPTIC TANK EFFLUENT PUMP OR GRAVITY (STEP/STEG) SEWER PROJECTS

2.1.7.1 APPLICABILITY

These criteria apply to STEP units discharging to pressurized common sewers, and to STEP or STEG units discharging to small-diameter gravity systems. Pressurized and small-diameter collectors have interactive hydraulic effects and solids handling limitations, which warrant a comprehensive engineering design.

These criteria do not apply to individual or single dwelling septic tank or grinder pump units discharging a conventional gravity sewer.

Septic tanks discharging to a drainfield.

Vacuum sewer collection systems.

2.1.7.2 STEP SYSTEMS

In a typical STEP system, household sewage is pretreated in a watertight septic tank where gross solids and grease are held back. A "clear" effluent from the mid-depth of the tank is transported to a common or lateral sewer. Usually the effluent is pumped from the septic tank under pressure to a small-diameter, pressurized collector sewer.

Effluent may also flow by gravity, where terrain allows, to small-diameter gravity collector lines.

2.1.7.3 SCOPE

A STEP/STEG system is considered to include all of its components beginning with the septic tanks, and ending at the point(s) of discharge into a conventional gravity sewer or treatment plant.

2.1.7.4 ADMINISTRATIVE REQUIREMENTS

All additions and extensions to existing STEP (or STEG) systems, as well as new systems, must be reviewed by the DIVISION OF WATER POLLUTION CONTROL.

The OWNER is defined as the municipality, sanitary district, private sewage utility or sanitary authority that is responsible for the operation of the system. The property being served is defined as the "USER".

Legal title to tanks, pumps, or other components must be vested with the OWNER. The objective of having title invested to the OWNER rather than the USER is to avoid potential for cost disputes over equipment selection and repair methods.

Regardless of where title is vested, the OWNER shall completely control all tanks, pumps, service lines and other components of the system on private property. This requirement is essential to assure operable hydraulics and overall system reliability.

The OWNER shall possess a recorded general easement or deed restriction to enter the private property being served, and to access the system and its components. Access must be guaranteed to operate, maintain, repair, restore service and remove sludge.

No system shall be operated without the direct field supervision of qualified collection operator certified by the STATE OF TENNESSEE. An operations and maintenance manual shall be submitted for review prior to startup.

OWNERS shall operate and maintain STEP/STEG facilities without interruption, sewage spills on the grounds, sewage backup into buildings, or other unhealthy conditions.

2.2 Design Considerations

2.2.1 Design Period

2.2.1.1 Collection Sewers (Laterals and Submains)

Collection sewers should be designed for the ultimate development of the tributary areas.

2.2.1.2 Main, Trunk and Interceptor Sewers

Selection of the design period for trunk and interceptor sewers should be based on evaluation of economic, functional, and other considerations. Some of the factors that should be considered in the evaluation are:

a. **Possible solids deposition, odor, and pipe corrosion that might occur at initial flows**
b. **Population and economic growth projections and the accuracy of the projections.**
c. **Comparative costs of staged construction alternatives.**
d. **Effect of sewer sizing on land use and development.**

2.2.2 Design Basis

New sewer systems shall be designed on the basis of per capita flows or alternative methods. Documentation of the alternative methods shall be provided.

2.2.2.1 Per Capita Flow

New sewer systems designed on the basis of an average daily per capita flow may be designed for flow equal to that set forth in Appendix 2-A. These figures are assumed to cover normal infiltration and inflow, but an additional allowance should be made where conditions are unfavorable. If there is an existing water system in the area, water consumption figures can be used to help substantiate the selected per capita flow. Generally, the sewers should be designed to carry, when running full, not less than the following:

a. **Lateral and Submains: Minimum peak design flow should be not less than 400 percent of the average design flow.**

   "Lateral" is defined as a sewer that has no other common sewers discharging into it.

   "Submain" is defined as a sewer that receives flow from one or more lateral sewers.

b. **Main, Trunk, and Interceptor Sewers: Minimum peak design flow should be not less than 250 percent of the average design flow.**

   "Main" or "trunk" is defined as a sewer that receives flow from one or more submains.

   "Interceptor" is defined as a sewer that receives flow from a number of main or trunk sewers, force mains, etc.

2.2.2.2 Alternative Methods

New sewer systems may be designed by alternative methods other than on the basis of per capita flow rates. Alternative methods may include the use of peaking factors of the contributing area, allowances for future commercial and industrial areas, separation of infiltration and inflow from the normal sanitary flow, and modification of per capita flow rates (based on specific data). Documentation of the alternative method used shall be provided When infiltration is calculated separately from the normal sanitary flow, the maximum allowable infiltration rate shall be 25 gallons per day per inch diameter of the sewer per mile of sewer.

2.2.3 Design Factors

The following factors must be considered in the design of sanitary sewers:

a. **Peak sewage flows from residential, commercial, institutional, and industrial sources**
b. **Groundwater infiltration and exfiltration**
c. **Topography and depth of excavation**
d. **Treatment plant location**
e. **Soils conditions**
f. **Pumping requirements**
g. **Maintenance, including manpower and budget**
h. **Existing sewers**
i. **Existing and future surface improvements**
j. **Controlling service connection elevations**

2.2.4 Design Definitions

2.3 Design and Construction Details

2.3.1 Gravity Sewers

2.3.1.1 Minimum Size

No sewer shall be less than 8 inches in diameter except that, in special cases, 6-inch-diameter sewer lines may be approved by the Department if they meet the following criteria:

a. The maximum number of services should not exceed 40 residences. This applies to 6" service lines as well as 6" mains.
b. A manhole shall be provided where the 6-inch connects to 8-inch or larger line. This does not include a 6-inch side sewer to serve 1 or 2 single-family dwellings.
c. A manhole or cleanout shall be provided at the end of the 6-inch line. This requirement shall be at the discretion of the Division.

d. Extension of the 6-inch line will not be possible at a later date.
e. The minimum slope allowable for 6-inch lines will be 0.60 feet per 100 feet.
f. Small diameter gravity (SDG) systems will be considered on a case by case basis. These systems should be discussed with TDEC personnel prior to initiation of detailed design work.

2.3.1.2 Depth

Generally, sewers should not be less than 2 ½ feet deep, but should be sufficiently deep to prevent freezing and physical damage and should receive sewage from existing dwellings by gravity.

2.3.1.3 Roughness Coefficient

The roughness coefficient should be documented for the type of pipe used. However, for ease of calculations, an "n" value of 0.0115 may be used in Manning's formula for the design of all sewer facilities.

2.3.1.4 Slope

All conventional gravity sewers shall be designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second. The following minimum slopes should be provided; however, slopes greater than these are desirable:

Table 2-1

Sewer Size (inches)	Minimum Slope (feet per 100 feet)
6	0.38
8	0.26
10	0.193
12	0.151
14	0.123
15	0.112
16	0.103
18	0.088
21	0.072
24	0.060
27	0.051
30	0.045
36	0.035
42	0.028
48	0.024

Under special conditions, slopes slightly less than those required for the 2.0-feet-per-second velocity when flowing full may be permitted. Such decreased slopes will only be considered where the depth of flow will be 0.3 of the diameter or greater for design average flow. Whenever such

decreased slopes are proposed, the design engineer shall furnish with his report his computations of the depths of flow in such pipes at minimum, average, and daily or hourly rates of flow. The maintaining sewage agency must recognize and accept in writing the problems of additional maintenance caused by decreased slopes.

Sewers shall be laid with uniform slope between manholes.

Sewers on 18 percent slope or greater shall be anchored securely with concrete anchors or equal. Suggested minimum anchorage spacing is as follows:

1. **Not over 36 feet center to center on grades 18 percent and up to 25 percent.**
2. **Not over 24 feet center to center on grades 25 percent and up to 35 percent.**
3. **Not over 16 feet center to center on grades 35 percent and over.**

2.3.1.5 Alignment

Generally, gravity sewers shall be designed with straight alignment between manholes. However, curved sewers may be approved where circumstances warrant, but only in large (i.e., 36" and larger) diameter segments.

2.3.1.6 Increasing Size

Where a smaller sewer joins a larger one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient. An approximate method for securing these results is to place the 0.8 depth point of both sewers at the same elevation.

2.3.1.7 High-Velocity Protection

Where velocities greater than 15 feet per second are expected, special provision shall be made to protect against internal erosion or displacement by shock.

2.3.2 Materials

Any generally accepted material for sewers will be given consideration. The material selected should be adapted to local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, abrasion and similar problems. Careful consideration should be given to pipes and compression joint materials subjected to corrosive or solvent wastes. Such pipe and compression joint material should be evaluated for vulnerability to chemical attack, chemical/stress failure and stability in

the presence of common household chemicals such as cooking oils, detergents and drain cleaners.

The specifications shall stipulate that the pipe interior, sealing surfaces, fittings and other accessories should be kept clean. Store pipe bundles on flat surfaces with uniform support. Stored pipe should be protected from prolonged exposure (six months or more) to sunlight with a suitable covering (canvas or other opaque material). Air circulation should be provided under the covering. Gaskets should not be exposed to oil, grease, ozone (produced by electric motors), excessive heat and direct sunlight. Consult with the manufacturers for specific storage and handling recommendations.

2.3.2.1 Rigid Pipe

Shall include, but are not limited to, vitrified clay, concrete, and cast iron pipe. Any rigid pipe shall have a minimum crushing strength of 2000 pounds per lineal foot. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.2 Semi-rigid Pipe

Shall include, but not be limited to, <u>Polyvinyl Chloride (PVC) composite (truss) pipe and</u> ductile iron. <u>PVC</u> composite pipe ends shall be sealed. <u>Rubber gasket</u> joints shall be specified. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.3 Flexible Pipe

Shall include, but not be limited to, polyvinyl chloride pipe (PVC), polyethylene pipe (PE), fiberglass composite pipe, reinforced plastic mortar pipe (RPM) and reinforced thermosetting resin pipe (RTR). PVC pipe should have a maximum Standard Dimension Ratio (SDR) of 35. All other flexible pipe that is not classified by the SDR system should have the same calculated maximum deflection under identical conditions as the SDR 35 PVC pipe.

Flexible pipe deflection under earth loading may be calculated using the formula presented in the ASCE/WPCF publication, <u>Design and Construction of Sanitary and Storm Sewers</u>.

All pipes should meet appropriate ASTM and/or ANSI specifications. It should be noted that ASTM D-3033 and D-3034 PVC pipes differ in wall thickness and have non-interchangeable fittings.

2.3.3 Pipe Bedding

All sewers shall be designed to prevent damage from superimposed loads. Proper allowance for loads on the sewer shall be made because of the width and depth of trench. Trench widths should be kept to a minimum.

Backfill material up to three feet above the top of the pipe should not exceed 6 inches in diameter at its greater dimension.

As a general rule, in roadways where cover is less than 4 feet, ductile iron pipe, solid wall flexible plastic pipe, or concrete encasement shall be used. In such cases, a minimum cover of six inches (12 inches for solid wall flexible plastic pipe) is required. For structural reasons, ductile iron pipe, concrete encasement, or relocation shall be required when culverts or other conduits are laid such that the top of the sewer is less than 18 inches below the bottom of the culvert or conduit.

Uncased borings are not permitted for pipe larger than 3 inches.

Special care shall be used in placing bedding in the haunch region.

2.3.3.1 Rigid Pipe

Bedding Classes A, B, or C as described in ASTM C-12 or WPCF MOP No. 9 (ASCE MOP No. 37) shall be used for all rigid pipe, provided the proper strength pipe is used with the specified bedding to support the anticipated load. Bedding and backfield shall be placed as described in ASTM C-12.

2.3.3.2 Semi-rigid Pipe

Bedding Classes, I, II, III or IV (ML and CL only) as described in ASTM D-2321 shall be used for all semi-rigid pipe provided with the specified bedding to support the anticipated load.

Underground installation of ductile iron pipe shall be done per ASTM A-746.

2.3.3.3 Flexible Pipe

Bedding Classes I, II, or III as described in ASTM D-2321 shall be used for all flexible pipe provided, the proper strength pipe is used with the specified bedding to support the anticipated load.

Bedding, haunching, initial backfill, and backfill shall be placed in accordance to ASTM D-2321.

It is recommended that polyethylene pipe is installed with Class I bedding material for bedding, haunching, and initial backfill as described in 2.3.3.4.

2.3.3.4 Alternate Bedding Option

As an alternative to sub-sections 2.3.3.1, 2.3.3.2 and 2.3.3.3, all sewers shall be bedded and backfilled with a minimum of six inches of Class I material over the top and below the invert of the pipe.

2.3.3.5 Deflection Testing

Deflection testing of all flexible pipes shall be required. The test shall be conducted after the backfill has been in place at least 24 hours.

No pipe shall exceed a deflection of 5%.

The test shall be run with a rigid ball or an engineer-approved 9-arm mandrel having a diameter equal to 95% of the inside diameter of the pipe. The test must be performed by manually pulling the test device through the line.

2.3.3.6 Check Dams

Check dams shall be installed in the bedding and backfill of all new or replaced sewer lines to limit the drainage area subject to the French drain effect of gravel bedding. Major rehabilitation projects should also include check dams in the design. Dams shall consist of compacted clay bedding and backfill at least three (3) feet thick to the top of the trench and cut into the walls of the trench two (2) feet. Alternatively, concrete may be used, keyed into the trench walls. Dams shall be placed no more than 500 feet apart. <u>The required location is upstream of each manhole. All stream crossings will include check dams on both sides of the crossing.</u>

2.3.4 Joints

The method of making joints and the materials used should be included in the specifications. Sewer joints shall be designed to eliminate infiltration and exfiltration to prevent the entrance of roots.

Elastomeric gaskets, other types of pre-molded (factory made) joints are required. The butt fusion joining technique is acceptable for polyethylene pipe. On concrete pipe of 36" and greater diameter, the Anderson type joint shall be required. Cement mortar joints are not acceptable. Field solvent welds for PVC, PVC Truss and PE pipe and fittings are not acceptable.

2.3.5 Leakage Testing

Leakage tests shall be specified.

2.3.5.1 Testing Methods

Testing methods may include appropriate water or low pressure air testing. The use of television cameras for inspection prior to placing the sewer into service and prior to acceptance is recommended.

2.3.5.2 Low Pressure Air Testing

Low-pressure air testing shall be performed as per ASTM C-828 on all gravity pipes. The time required for the pressure to drop from the stabilized 3.5 psig to 2.5 psig should be greater than or equal to the minimum calculated test time (the test criteria should be based on the air loss rate. The testing method should take into consideration the range in groundwater elevations projected and the situation during the test. The height of the groundwater should be measured from the top of the invert (one foot of H_20 = 0.433 psi).

Table 2-2 gives the minimum test times and allowable air loss values for various pipe sizes per 100 ft.:

Table 2-2

Pipe Size (inches)	Time, T (sec/100 ft)	Allowable Air Loss, Q (ft3/min)
6	42	2.0
8	72	2.0
10	90	2.5
12	108	3.0
15	126	4.0
18	144	5.0
21	180	5.5
24	216	6.0
27	252	6.5
30	288	7.0

2.3.6 Low Pressure Systems

Low-pressure sewer systems are considered Developmental Technology.

2. 3.6.1 Application

Low-pressure systems should be considered for situations in which gravity sewers are extremely costly or impractical, such as rock or high groundwater table.

2.3.6.2 Grinder Pumps

All raw wastewater should be collected from individual buildings/dwellings and transported to the pressure or gravity system by appropriately sized grinder pumps. A SEPTIC TANK/GREASE TRAP MUST BE USED PRIOR TO THE GRINDER PUMP FOR RESTAURANTS**.**

Grinder pumps do not require a septic tank except when used at restaurants..

All pumps shall have operating curves that do not allow backflow under maximum head conditions.

Pumps shall be watertight and located above the seasonal groundwater table where possible.

Odor considerations must be evaluated.

2.3.6.3 Septic Tank Effluent Pump (STEP) System

All STEP installations require careful attention to design details and construction techniques. The following criteria must be considered:

A. There are two methods of designing the STEP. The preferred method is to have the effluent pump in the septic tank itself and the other method is to have a separate enclosure for the effluent pump.

B. All STEPs must have a watertight designed septic tank. Retrofitting a septic tank to meet the requirements of a STEP is not acceptable.

C. If a STEP is to be retrofitted to an existing septic tank and drain field, a positive means of preventing groundwater from backing up through the drainfield to the STEP shall be provided.

D. The STEP shall be located as close as possible to the septic tank.

E. Electrical power should be supplied through the main circuit box. Electricity is furnished to a separate circuit box installed on the exterior wall of the building, near the STEP.

2.3.6.4 Provision for Maintenance

Approval of a low-pressure sewer system shall be contingent on the following minimum provisions being made for operation and maintenance.

A. An <u>adequate reserve stock</u> of replacement pumping units shall be maintained by the municipality or utility.
B. There shall be qualified grinder pump or STEP maintenance personnel available as long as the system exists.
C. There shall be a written service agreement with the manufacturer assuring the availability of factory-trained maintenance personnel, the continued availability of standby equipment and replacement parts, other provisions assuring the Department that breakdowns will be repaired within 24 hours, and a written preventive maintenance plan.
D. STEPs shall be owned by the municipality and shall be maintained by the municipality or its assignee but, in any case, under supervision of the municipality.

E. The owner of each building served by a grinder pump or STEP will give an easement and/or right-of-way to the municipality for maintenance and inspection services. All persons exercising rights under this document shall be suitably bonded against theft and/or damages to the building and its contents. Notification of entry shall be a matter between owner/occupant/user and the municipality.
F. Replacement parts should be available for the entire life of the pumping unit. If parts become unavailable, provision should be made to replace pumps that fail with improved or updated models. A sinking fund should be established for this replacement and should take into account life expectancy of the pumping unit and regular maintenance cost.

2.3.6.5 Hydraulic

Calculations are of extreme importance, due to the fact that head losses within the low-pressure system will change each time a pump is activated. For this reason, future connections to a low-pressure system may not be feasible.

2.3.6.6 Minimum Velocity

The minimum operating velocity in the pressure system shall be 2 feet per second.

2.3.6.7 Flushing

There shall be a means of cleaning the system, particularly to clear any settleable solids or grease accumulation.

2.3.6.8 Pressure Testing

There shall be means for isolating and pressurizing sections of the system to detect and locate leaks.

2.3.6.9 Alarms

There should be a dual audio and visual warning system both inside the building and out, indicating malfunction of the pump. The high-level (in storage tank) warning system should also be a dual system. The warning systems should be an audio/visual one.

2.3.6.10 Cleanouts

Cleanouts should be provided at maximum of 400- foot intervals.

2.3.6.11 Ventilation

Ventilation of the pump station should be provided via house vents where allowable or through a separate system.

2.3.7 Manholes

2.3.7.1 Location

Manholes shall be installed at the end of each line of 8-inch diameter or greater unless the 8-inch line is expected to be extended in the foreseeable future; in which case a cleanout shall be installed at the end of the line; at all changes in grade, size, or alignment; at all intersections; and at distances not greater than 400 feet for sewers 15 inches or less and 500 feet for sewer 18 inches to 30 inches (except that distances up to 600 feet may be approved in cases where adequate modern cleaning equipment for such spacing is provided). Greater spacing may be permitted in larger sewers and in those carrying a settled effluent. Cleanouts may be used in lieu of manholes at the end of lines 6 or 8 inches in diameter and not more than 150 feet long.

With prior municipality or utility approval greater distances between manholes may be allowed.

2.3.7.2 Drop Connection

An outside drop connection shall be provided for a sewer entering a manhole at an elevation of 24 inches or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches, the invert should be filleted to prevent solids deposition.

2.3.7.3 Diameter

The minimum diameter of manholes should be 48 inches; larger diameters are preferable. The minimum clear opening in the manhole frame should be <u>24 inches to provide safe access for emergencies</u>.

Manholes connecting significant industries to the system should be larger, to provide space for monitoring and sampling equipment.

2.3.7.4 Flow Channels

Flow channels in manholes shall be of such shape and slope to provide smooth transition between inlet and outlet sewers and to minimize turbulence. <u>A minimum slope of 0.1 ft. drop across the bottom of the manhole must be provided to maintain cleaning and the hydraulic gradient</u>. Channeling height shall be to the crowns of the sewers. Benches shall be sloped from the manhole wall toward the channel to prevent accumulation of solids.

2.3.7.5 Watertightness

Watertight manhole covers shall be used wherever the manhole tops may be flooded. Manholes of brick or segmented block are not acceptable.

2.3.7.6 Testing

All new or rehabilitated manholes shall be vacuum tested to assure watertightness before backfilling. The exterior surface must be painted with waterproofing material as the vacuum is being pulled to seal the pores of the concrete.

2.3.7.7 Connections

Line connections directly to the manholes or to short stubs integral with the manholes should be made with flexible joints. Flexible joints are joints that permit the manholes to settle without destroying the watertight integrity of the line connections.

2.3.7.8 Ventilation

Ventilation of gravity sewer systems should be considered where continuous watertight sections greater than 1,000 feet in length are incurred. Vent height and construction must consider flood conditions.

2.3.7.9 Frames, Covers, and Steps

Frames, covers, and steps shall be of suitable material and designed to accommodate prevailing site conditions and to provide for a safe installation. Materials used for manhole steps should be highly corrosion-resistant. The use of galvanized steel should be avoided and aluminum or plastic with reinforcing bar is preferred.

2.4 Special Details

2.4.1 Protection of Water Supplies

2.4.1.1 Water Supply Interconnections

There shall be no physical connection between a public or private potable water supply system and a sewer or appurtenance thereto.

2.4.1.2 Relation to Waterworks Structures

It is generally recognized that sewers shall be kept remote from public water supply wells or other water supply sources and structures.

2.4.1.3 Relation to Water Mains

Horizontal Separation: Whenever practical, sewers should be laid at least 10 feet horizontally from any existing or proposed water main. The distance should be measured edge to edge. Should local conditions prevent a lateral separation of 10 feet, a sewer may be laid closer than 10 feet to a water main if it is laid in a separate trench and if the elevation of the top (crown) of the sewer is at least 18 inches below the bottom (invert) of the water main.

Vertical Separation: Whenever sewers must cross under water mains, the sewer shall be laid at such elevation that the top of the sewer is at least 18 inches below the bottom of the water main. When the elevation of the sewer cannot be varied to meet the above requirement, the water main shall be relocated to provide this separation or reconstructed with mechanical-joint pipe for a distance of 10 feet on each side of the sewer. One full length of water main should be centered over the sewer so that both joints will be as far from the sewer as possible.

When it is impractical to obtain proper horizontal and vertical separation as stipulated above, the sewer shall be designed and constructed equal to the water main pipe and shall be pressure-tested to assure water-tightness (see drinking water criteria). Such arrangements are discouraged and adequate reason shall be provided to justify the design. Any variations from this statement must be approved by the DIVISION OF WATER POLLUTION CONTROL prior to construction..

2.4.2 Backflow Preventers

State approved reduced pressure backflow prevention devices are required on all potable water mains serving the wastewater treatment plant or lift station. A list of approved backflow preventers may be obtained from the Division of Water Supply.

Backflow preventers shall be installed as per the Design Criteria for Community Public Water Systems, Division of Water Supply. Belowground pit installations are not acceptable.

2.4.3 Sewers in Relation to Streams

2.4.3.1 Location of Sewers in Streams

The top of all sewers entering or crossing streams shall be at a sufficient depth below the natural bottom of the streambed to protect the sewer line. In general, the following cover requirements must be met:

a. **One (1) foot of cover (poured in place concrete) is required where the sewer is located in rock.**
b. **Three (3) feet of cover is required in stabilized stream channels.**
c. **Seven (7) feet of cover or more is required in shifting stream channels.**

Sewers located along streams shall be located outside of the streambed and sufficiently removed therefrom to minimize disturbance or root damage to streamside trees and vegetation.

Sewer outfalls, headwalls, manholes, gateboxes or other structures shall be located so they do not interfere with the free discharge of flow of the stream.

Sewers crossing streams shall be designed to cross the stream as nearly perpendicular to the stream flow as possible and shall be free from change in grade. To prevent the French drain effect of the sewer crossing the stream , check dams must be installed up stream and down stream in the pipe conduit trench. This must be separate from any concrete encasement.

2.4.3.2 Construction

Sewers entering or crossing streams shall be constructed of ductile iron pipe with mechanical joints, concrete encased, or shall be so otherwise constructed that they will remain watertight and free from changes in alignment or grade. Sewer systems shall be designed to minimize the number of stream crossings. The construction methods that will minimize siltation shall be employed. Upon completion of construction, the stream shall be returned as nearly as possible to its original condition. The stream banks shall be seeded, planted or other erosion prevention methods employed to prevent erosion. Stream banks shall be sodded, if necessary, to prevent erosion. Where tree canopy has been removed, replacement trees shall be planted of natural species. The consulting engineer shall specify the specific method or methods to be employed in the construction of the sewers in or near the stream to control siltation.

During construction of sewerage projects, the contractor shall be prohibited by clauses in the specifications from unnecessarily disturbing or uprooting trees and vegetation along the stream bank and in the vicinity of the stream, dumping of soil and debris into streams and/or on banks of streams, changing course of the stream without encroachment permit, leaving cofferdams in streams, leaving temporary stream crossings for equipment, operating equipment in the stream, or pumping silt-laden water into the stream.

Provisions shall be made in the specifications to retard the rate of runoff from the construction site and control disposal of runoff, including liberal use of entrenched silt fencing to trap sediment resulting from construction in temporary or permanent silt-holding basins, including pump discharges resulting from dewatering operations; to deposit out of the flood plain area all material and debris removed from the stream bed.

Specifications shall require that cleanup, grading, seeding, planting or restoration of the work area shall be carried out as early as practical as the construction proceeds.

Uncased borings are not permitted.

The design engineer is encouraged to read and become familiar with the Tennessee Erosion and Sediment Control Handbook available from the Department.

2.4.3.3 Special Construction Requirements

Special design requirements shall be employed to prevent stream drainage from sinking at the crossing and following along the sewer pipe bedding. This can be accomplished with an in- trench impounding structure of compacted clay or other impermeable materials. Other proposals will be considered.

2.4.3.4 Aerial Crossings

Sewers laid on piers across ravines or streams shall be allowed when it can be demonstrated that no other practical alternative exists or, in the design engineers judgement, other methods will not be as reliable.

Support shall be provided for all joints. All supports shall be designed to prevent frost heave, overturning or settlement. Precautions against freezing, such as insulation or increased slope, shall be provided. Expansion jointing shall be provided between aboveground and belowground sewers. The impact of floodwaters and debris shall be considered. The bottom of the pipe should be placed no lower than the elevation of the fifty-(50) year flood stage.

2.4.3.5 Permits

It is the owner's responsibility to obtain all necessary permits along streams or rivers; i.e., Corps of Engineers, TVA, or the Natural Resources Section of the Division of Water Pollution Control.

2.4.4 Inverted Siphons

Under normal conditions inverted siphons should not be used; but if they are, then the following conditions <u>must</u> be met:

Inverted siphons shall have a minimum of two barrels, with a minimum pipe size of six inches and shall be provided with necessary appurtenances for convenient flushing and maintenance. The manholes shall have adequate clearances for rodding. Sufficient head shall be provided and pipe sizes selected to secure velocities of at least 3.0 feet per second for average flows.

The inlet and outlet details shall be arranged so that the normal flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning. When inverted siphons are used, the design engineer must furnish hydraulic calculations the plans. Proper access must be maintained.

2.5 General Requirements for Pump Stations

2.5.1 Location and Flood Protection

Sewage pump stations should be located as far as practicable from present or proposed built-up residential areas, and an all-weather road should be provided. Noise control, odor control, and station architectural design should be taken into consideration. Sites for stations shall be of sufficient size for future expansion or addition, if applicable. The station site (larger stations) shall also be fenced and locked.

The station's operational components shall be located at an elevation that is not subject to the 100-year flood or shall otherwise be adequately protected against the 100-year flood damage.

Where the wet well is at a depth greater than the watertable elevation, special provisions shall be made to ensure watertight construction of the wet well. Any connections to the pump station should be made at an elevation higher than the maximum watertable elevation, where possible.

2.5.2 Pumping Rate and Number of Units

At least two pump units shall be provided, each capable of handling the expected maximum flow. Pump head and system head curves shall be submitted to the Department for review purposes.

Where three or more units are provided, they shall be designed to fit actual flow conditions and must be of such capacity that, with any one unit out of service, the remaining units will have capacity to handle the maximum sewage flow. <u>The number of pump units may be controlled by the reliability classification of the adjacent receiving waters. See Chapter 1.3.11.3</u>.

When the station is expected to operate at a flow rate less than one half the average design flow for an extended period of time, the design shall address measures taken to prevent septicity due to long holding times in the wet well.

Consideration should be given to the use of variable-speed or multiple staged pumps, particularly when the pump station delivers flow directly to a treatment plant, so that sewage will be delivered at approximately the same rate as it is received at the pump station.

2.5.3 Grit and Clogging Protection

Where it may be necessary to pump sewage prior to grit removal, the design of the wet well should receive special attention, and the discharge piping should be designed to prevent grit settling in pump discharge lines of pumps not operating.

For large pump stations (generally, larger than 1 MGD) handling raw sewage, consideration should be given to installation of readily accessible bar racks with clear openings not exceeding 2-1/2 inches, unless pneumatic ejectors are used or special devices are installed to protect the pumps from clogging or damage. Where the size of the installation warrants, a mechanically cleaned bar screen with grinder or comminution device is recommended. Where screens are located below ground, convenient facilities must be provided for handling screenings. For the larger or deeper stations, duplicate protection units, each sized at full capacity, are preferred.

2.5.4 Pumping Units

2.5.4.1 Pump Openings

Pumps shall be capable of passing spheres of at least 3 inches in diameter. Pump suction and discharge openings shall be at least 4 inches in diameter.

2.5.4.2 Priming

Pumps shall be so placed that under normal operating conditions they will operate under a positive suction head (except for suction lift pumps).

2.5.4.3 Intake

Each pump should have an individual intake. Wet well design should be such as to avoid turbulence near the intake.

2.5.4.4 Controls

Control float switches should be so located as not to be affected by the flows entering the wet well or by the suction of the pumps. Controls must be able to activate additional pumps if water in the wetwell continues to rise. Air-operated pneumatic controls are preferred for all sewage pump stations. Provisions should be made to automatically alternate the pumps in use. Pump stations with motors and/or controls below grade should be equipped with a

secure external disconnect switch. If float switches are used, an "intrinsically safe" power source must be considered.

2.5.5 Flow Measurement

Suitable devices for measuring sewage flow should be provided at pumping stations with flow capacity greater than 1.0 million gallons per day (MGD). Hour timers (totalizers) shall be installed on all pumps unless otherwise approved by the Department.

2.5.6 Alarm System

An alarm system should be provided for all pumping stations. Consideration of telemetry alarm to 24-hour monitoring stations or telephone alarms to duty personnel should be given when reliability classification or property damage warrants it. When telemetry is not used, an audiovisual device should be installed at the station for external observation.

An alarm system may not be needed, in certain cases, where a utility has adopted a daily inspection routine. A statement from the utility, indicating that is has a daily inspection program, will be required. In certain cases, an alarm system may be required regardless of any other practices.

Alarms for high wet well and power failure shall be provided, as a minimum, for all pump stations. For larger stations, alarms signalizing pump and other component failures or malfunctions should also be provided.

A backup power supply, such as a battery pack with an automatic switchover feature, should be provided for the alarm system, such that a failure of the primary power source will not disable the alarm system. Test circuits should be provided to enable the alarm system to be tested and verified that it is in good working order.

2.5.7 Emergency Overflow Pumping

Regardless of the type of emergency power standby system provided, <u>a riser from the force main with rapid connection capabilities and appropriate valves shall be provided for all lift stations to hook up portable pumps.</u>

2.6 Special Details

2.6.1 General

2.6.1.1 Materials

In the selection of materials, consideration should be given to the presence of hydrogen sulfide and other corrosive gases, greases, oils, and other constituents frequently present in sewage.

2.6.1.2 Electrical Equipment

Electrical systems and components (e.g., motors, lights, cables, conduits, switchboxes, control circuits) in enclosed or partially enclosed spaces where flammable mixtures occasionally may be present (including raw sewage wet wells) shall comply with the National Electrical Code requirements for Class I Division 1 locations.

2.6.1.3 Water Supply

There shall be no physical connection between any potable water supply and a sewage pumping station that under any conditions might cause contamination of the potable water supply. If a potable water supply is brought to the station, it shall comply with conditions stipulated in section 2.4.2.

2.6.1.4 Lighting

Adequate lighting for the entire pump station shall be provided.

2.6.1.5 Pump and Motor Removal

Provisions shall be made to facilitate removing pumps, motors, and other equipment, without interruption of system service.

2.6.1.6 Access

Suitable and safe means of access should be provided to equipment requiring inspection or maintenance. Stairways and ladders shall satisfy all OSHA requirements. Consideration should be given to fencing pump stations to discourage the entrance of unauthorized persons.

2.6.1.7 Valves and Piping

Suitable shutoff valves shall be placed on suction and discharge lines of each pump for normal pump isolation. A check valve should be placed on each discharge line between the shutoff valve and the pump. Pump suction and discharge piping should not be less than 4 inches in diameter except where design of special equipment allows.

The velocity in the suction line should not exceed 6 feet per second and, in the discharge piping, 8 feet per second. A separate shutoff valve is desirable on the common line leaving the pump station.

2.6.1.8 Ventilation

Ventilation should be provided for all pump stations during all periods when the station is manned. Where the pump is below ground, mechanical ventilation is required and should be arranged so as to independently ventilate the dry well. If screens or mechanical equipment, which might require periodic maintenance and inspection, are located in the wet well, then it should also be mechanically ventilated. There should be no interconnection between the wet well and the dry well ventilation systems. In pits over 15 feet deep, multiple inlets and outlets are desirable. Dampers should not be used on exhaust or fresh air ducts, and fine screens or other obstructions in air ducts should be avoided to prevent clogging. Switches for operation of ventilation equipment should be marked and conveniently located above grade and near the pump station entrance. Consideration should be given also to automatic controls where intermittent operation is used. The fan wheel should be fabricated from nonsparking material. In climates where excessive moisture or low temperature is a problem, consideration should be given to installation of automatic heating and/or dehumidifying equipment. Where heat buildup from pump motors may be a problem, consideration should be given to automatic ventilation to dissipate motor heat.

2.6.2 Wet Well - Dry Well Stations

2.6.2.1 Separation

Wet and dry wells, including their superstructures, should be completely separated.

Where continuity of pump station operation is necessary, consideration should be given to dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning.

2.6.2.2 Wet Well Size

The effective capacity of the wet well should be evaluated based on pumping requirements and reliability classifications.

2.6.2.3 Floor Slope

The wet well floor should have a minimum slope of 1-to-1 in the hopper bottom. The horizontal area of the hopper bottom should be

no greater than necessary for proper installation and function of the inlet.

2.6.2.4 Ventilation

Wet well ventilation may be either continuous or intermittent. Ventilation, if continuous, should provide at least 12 complete air changes per hour; if intermittent, at least 30 complete air changes per hour. Such ventilation should be accomplished by introduction of fresh air into the wet well by mechanical means.

Dry well ventilation may be either continuous or intermittent. Ventilation, if continuous, should provide at least 6 complete air changes per hour; if intermittent, at least 30 complete air changes per hour.

Portable ventilation equipment is acceptable for small pump stations where occupancy is rare.

2.6.2.5 Dry Well Dewatering

A separate sump pump should be provided in the dry wells to remove leakage or drainage with the discharge above the high water level of the wet well. Water ejectors connected to a potable water supply will not be approved. All floor and walkway surfaces should have an adequate slope to a point of drainage.

2.6.3 Suction Lift Stations

2.6.3.1 Priming

Conventional suction-lift pumps should be of the self-priming type, as demonstrated by a reliable record of satisfactory operation. The maximum recommended lift for a suction lift pump station is 15 feet, using pumps of 200 gallons per minute (gpm) capacity or less.

2.6.3.2 Capacity

The capacity of suction lift pump stations should be limited by the net positive suction head and specific speed requirements, as stated on the manufacturer's pump curve, for the most severe operating conditions.

2.6.3.3 Air Relief

a. Air Relief Lines

All suction lift pumps must be provided with an air relief line on the pump discharge piping. This line should be located at the maximum elevation between the pump discharge flange and the discharge check valve to ensure the maximum bleed-off of entrapped air. Air relief piping shall be sized appropriately. A separate air relief line shall be provided for each pump discharge. The air relief line should terminate in the wet well or suitable sump and be open to the atmosphere.

b. Air Relief Valves

Air relief valves should be provided in air relief lines on pumps not discharging to gravity sewer collection systems. The air relief valve should be located as close as practical to the discharge side of the pump.

2.6.3.4 Pump Location

Suction lift pumps should not be located within the wet well.

2.6.3.5 Access to Wet Well

Access to the wet well should not be through the dry well, and the dry well should have a gastight seal when mounted directly above the wet well.

2.6.4 Submersible Pumps

2.6.4.1 Pump Removal

Submersible pumps should be readily removable and replaceable without dewatering the wet well or requiring personnel to enter the wet well. Continuity of operation of the other units should be maintained.

A hoist and accessories for removing the pumps from the wet well should be provided.

2.6.4.2 Controls

The control panel should be located outside the wet well and suitably protected from weather, humidity, and vandalism.

2.6.4.3 Valves

All control valves on the discharge line for each pump should be placed in a convenient location outside the wet well in separate pits and be suitably protected from weather and vandalism. Outside valve covers should not be installed.

2.6.4.4 Submergence

Positive provision, such as backup controls, should be made to assure submergence of the pumping units.

2.7 Operability and Reliability

2.7.1 Objective

The objective of reliability is to prevent the discharge of raw or partially treated sewage to any waters and to protect public health by preventing backup of sewage and subsequent discharge to basements, streets, and other public and private property.

2.7.2 Backup Units

A minimum of two pumps shall be provided in each station in accordance with section 2.5.2.

2.7.3 Emergency Power Supply

2.7.3.1 General

Provision of an emergency power supply for pumping stations (and treatment plants) should be made, and may be accomplished by connection of the station to at least two independent public utility sources, or by provision in-place internal combustion engine equipment that will generate electrical or mechanical energy, or by the provision of portable pumping equipment. Emergency power must be provided for all stations which are 1 MGD or larger, or as determined by the reliability classification. See Chapter 1.3.11.5.

Emergency power shall be provided that, alone or combined with storage, will prevent overflows from occurring during any power outage that is equal to the maximum outage in the immediate area during the last 10 years. If available data were less than 10 years, an evaluation of a similar area served by the power utility for 10 years would be appropriate.

2.7.3.2 In-Place Equipment

Where in-place internal combustion equipment is utilized, the following guidelines are recommended:

A. Placement

The unit should be bolted in place. Facilities should be provided for unit removal for purposes of major repair or routine maintenance.

B. Controls

Provision should be made for automatic and manual startup and cut-in.

C. Size

Unit size should be adequate to provide power for lighting and ventilating systems and such further systems that affect capability and safety as well as the pumps.

D. Engine Location

The unit internal combustion engine should be located above grade, with suitable and adequate ventilation of exhaust gases.

E. Underground Fuel Storage Tank

If the fuel tank for the generator is to be placed below ground level, design and construction must conform to the applicable requirements of Federal Regulations 40 CFR 280 and 281. Contact the Tennessee Division of SUPERFUND, Underground Storage Tank Program, for guidance.

2.7.3.3 Portable Equipment

Where portable equipment is utilized, the following guidelines are recommended:

Pumping units should have connections to operate between the wet well and the discharge side of station, and the station should be provided with permanent fixtures that will facilitate rapid and easy

connection of lines. Electrical energy generating units should be protected against burnout when normal utility services are restored, and should have sufficient capacity to provide power for lighting and ventilating systems and any other station systems affecting capability and safety, in addition to the pumping units.

2.7.4 Storage

Where storage is provided in lieu of an emergency power supply, wet well and tributary main capacity above the high-level alarm should be sufficient to hold the peak flow expected during the maximum power outage duration during the last 10 years.

2.8 Force Mains

2.8.1 Size

Minimum size force mains should be not less than 4 inches in diameter, except for grinder pumps, septic tank effluent or vacuum applications.

2.8.2 Velocity

At pumping capacity, a minimum self-scouring velocity of 2 feet per second (fps) should be maintained unless flushing facilities are provided. Velocity should not exceed 8 feet per second.

2.8.3 Air Relief Valve

An air relief valve shall be placed at the necessary high points in the force main to relieve air locking.

2.8.4 Termination

The force main shall enter the receiving manhole with its centerline horizontal and with an invert elevation that will ensure a smooth flow transition to the gravity flow section; but in no case shall the force main enter the gravity sewer system at a point more than 1 foot above the flow line of the receiving manhole. The design should minimize turbulence at the point of discharge.

Consideration should be given to the use of inert materials or protective coatings for the receiving manhole to prevent deterioration as a result of hydrogen sulfide or other chemicals where such chemicals are present or suspected to be present because of industrial discharges or long force mains.

2.8.5 Materials of Construction

The pipe material should be adapted to local conditions, such as character of industrial wastes, soil characteristics, exceptionally heavy external loadings, internal erosion, corrosion, and similar problems.

Installation specification shall contain appropriate requirements based on the criteria, standards, and requirements established by the industry in its technical publications. Requirements shall be set forth in the specifications for the pipe and methods of bedding and back-filling thereof so as not to damage the pipe or its joints, impede cleaning operations, not create excessive side fill pressures or ovaling of the pipe, nor seriously impair flow capacity.

All pipes shall be designed to prevent damage from superimposed loads. Proper allowance for loads on the pipe shall be made because of the width and depth of trench.

2.8.6 Pressure Tests

Before back filling, all force mains shall be tested at a minimum pressure of at least 50 percent above the design operating pressure for at least 30 minutes. Leakage shall not exceed the amount given by the following formula:

$$L = \frac{ND(P)^{.5}}{7{,}400}$$

Where L is allowable leakage in gallons per hour,
N is the number of pipe joints,
D is the pipe diameter in inches,
P is the test pressure in psi.

2.8.7 Anchorage

Force mains shall be sufficiently anchored within the pump station and throughout the line length. The number of bends shall be as few as possible. Thrust blocks, restrained joints, and/or tie rods shall be provided where restraint is needed.

2.8.8 Friction Losses

A C factor shall be used that will take into consideration the conditions of the force main at its design usage. A pipe that is coated with grease after several years will not have the same C factor as it did when it was first placed into operation.

2.8.9 Water Hammer

The force main design shall investigate the potential for the existence of water hammer.

Appendix 2C:
Sample Specifications

VACUUM TESTING OF MANHOLES

The method of vacuum testing manholes REQUIRES the use of the following criteria:

1. This method is applicable to all manholes.
2. All lifting holes and exterior joints shall be filled and pointed with non-shrink grout for concrete manholes or sealed with compatible sealant for other materials. The exterior of the manhole must be painted as the vacuum is being applied to seal the pores of the concrete.
3. Manholes are to be tested immediately after assembly or construction and before back-filling. No standing water shall be allowed in the manhole excavation, which may affect the accuracy of the test.
4. All pipes and other openings into the manhole shall be suitably plugged in such a manner as to prevent displacement of the plugs while the vacuum is pulled.
5. Installation and operation of the vacuum equipment and indicating devices shall be in accordance with equipment specifications and instructions provided by the manufacturer.
6. The test head may be placed in the cone section of the manhole. The rim-cone is not usually tested.
7. A vacuum of 10.0 inches of mercury shall be drawn. The time for the vacuum to drop to 9.0 inches of mercury shall be recorded.
8. Acceptance for 4-ft. diameter manholes shall be defined as when the time to drop to 9 inches of mercury meets or exceeds the following:

MANHOLE DEPTH	**DIAMETER**	**TIME TO DROP 1" HG**
4 ft to 10 ft	**4 ft**	**75 seconds**
10 ft. to 15 ft.	**4 ft.**	**90 seconds**
15 ft. to 25 ft.	**4 ft.**	**105 seconds**

9. For manholes 5 ft. in diameter, add an additional 15 seconds and for manholes 6 ft. in diameter, add an additional 30 seconds to the time requirements for four foot diameter manholes.

10. If the manhole fails the test, necessary repairs shall be made and the vacuum test repeated until the manhole passes the test.
11. If the manhole joint mastic or gasket is displaced during the vacuum test, the manhole shall be disassembled and the seal replaced.

Appendix 2C

Appendix- 2-A
Table for
DESIGN BASIS FOR NEW SEWAGE WORKS

Discharge Facility	Design Units	Flow (gpd)	BOD (lb/day)	TSS (lb/day)	Flow (hr)
Dwellings	per person	100	0.17	0.2	24
School with showers and cafeteria	per person	16	0.04	0.04	8
School without showers and with cafeteria	per person	12	0.025	0.025	8
Boarding School	per person	75	0.2	0.2	16
Motels at 65 gal/person (rooms only)	per person	130	0.26	0.26	16
Trailer courts at 3 persons/trailer	per trailer	225	0.6	0.6	24
Restaurants	per seat	40	0.2	0.2	16
Interstate or through highway restaurants	per seat	180	0.7	0.7	16
Interstate rest areas	per person	5	0.01	0.01	24
Service stations	per vehicle serviced	10	0.01	0.01	16
Factories	per person per 8 hr shift	25	0.05	0.05	Operating Period
Shopping center (no food)	per 1,000 sq. Ft. Of floor	150	0.01	0.01	12
Hospitals	per bed	300	0.6	0.6	24
Nursing home (add 75 gals for laundry	per bed	120	0.3	0.3	24
Homes for the Aged	per bed	60	0.2	0.2	24
Child Care Center	per child and adult	10	0.01	0.01	Operating period
Laundromats, 9 to 12 machines	per machine	250	0.3	0.3	16
Swimming pools	per swimmer	10	0.001	0.001	12
Theaters, auditorium type	per seat	5	0.01	0.01	12
Picnic areas	per person	5	0.01	0.01	12
Resort camps, day & night with limited plumbing	per campsite	50	0.05	0.05	24
Luxury camps with flush toilets	per campsite	100	0.1	0.1	24
Churches (no kitchen)	per seat	3	0.005	0.005	Operating period

*** Includes normal infiltration**

Note: In all cases use actual data from similar facilities when possible. Note variations due to factors such as age, water conservation, etc. Submit all design data used.

Section 10

Pumps

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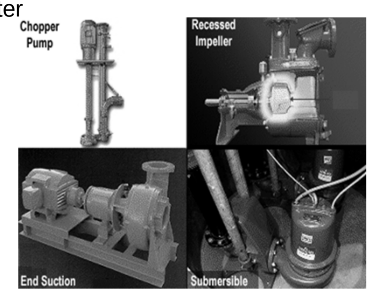
WASTEWATER PUMPS AND EQUIPMENT MAINTENANCE

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

TDEC - Fleming Training Center 2

Types of Pumps

- Classified by character of material handled:
  - Raw wastewater
  - Grit
  - Sludge
  - Effluent



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General Considerations

- Centrifugal pumps: wastewater
- Piston or diaphragm pumps: heavy solids
- Gear and piston pumps: high pressures
- Turbine or propeller pumps: mixing air or chemicals

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Types of Pumps

- Positive-Displacement Pumps
  - Metering pumps – sometimes used to feed chemicals
  - Piston pump
  - Screw pump
- Velocity Pumps
  - Vertical turbine
  - Centrifugal
    - Most common type in wastewater lift stations

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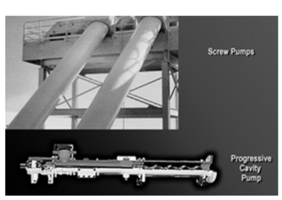
Positive-Displacement Pumps

- Sludge & chemical feed pumps
- Less efficient than centrifugal pumps
- **Cannot operate against a closed discharge valve**



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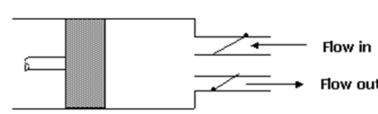
Positive-Displacement Pumps

- Reciprocating (piston) pump - piston moves back and forth in cylinder, liquid enters and leaves through check valves



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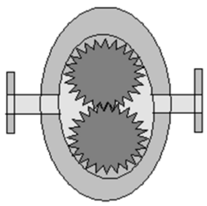
Positive-Displacement Pumps



- Rotary pump - Use lobes or gears to move liquid through pump

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Screw Pumps

- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point

Incline screw pumps handle large solids without plugging

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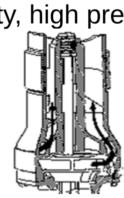
Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water

Volute



Diffuser

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Vertical Wet Well Pumps

- Has a vertical shaft, diffuser-type centrifugal pump with the pumping element suspended from the discharge piping.
- The needs of a given installation determines the length of discharge column
- The pumping bowl assembly may connect directly to the discharge head for shallow sumps, or may be suspended several hundred feet for raising water from wells
- Vertical turbine pumps are used to pump water from deep wells and may be of the single-stage or multistage type

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Velocity Pump Design Characteristics

- Axial - flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump instead of being thrown outward
  - High volume, but limited head
  - Not self-priming

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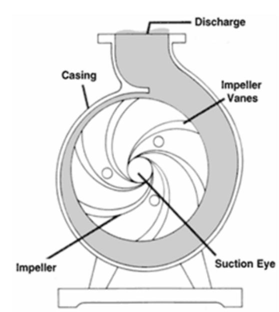
Velocity Pump Design Characteristics

- Radial flow designs
  - Water comes in through center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
  - The discharge is perpendicular to the pump shaft



Velocity Pump Design Characteristics

- Mixed - flow designs
  - Has features of axial and radial flow
  - Works well for water with solids

Centrifugal Pump

- Basically a very simple device: an impeller rotating in a casing
- The impeller is supported on a shaft, which in turn, is supported by bearings
- Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge

Most Common Centrifugal Pumps

- Horizontal non-clog type
- Vertical ball bearing type
- Propeller type

Advantages of Centrifugal Pumps

- Wide range of capacities
- Uniform flow at a constant speed and head
- Low cost
- Ability to be adapted to various types of drivers
- Moderate to high efficiency
- No need for internal lubrication

Disadvantages of Centrifugal Pumps

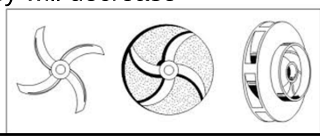
- Efficiency is limited to very narrow ranges of flow and head
- Flow capacity greatly depends on discharge pressure
- Generally no self-priming ability
- Can run backwards if check valve fails and sticks open
- Potential impeller damage if pumping abrasive water

Let's Build a Centrifugal Pump

- First we need a device to spin liquid at high speeds – an impeller
  - This is the heart of our pump
  - As the impeller spins, liquid between the blades is impelled outward by centrifugal force
  - As liquid in the impeller moves outward, it will suck more liquid behind it through this eye, provided it is not clogged.
    - If there is any danger that foreign material may be sucked into the pump, clogging or wearing of the impeller unduly, provide the intake end of the suction piping with a suitable screen

Impeller

- Bronze or stainless steel
- Closed; some single-suction have semi-open; open designs
- Inspect regularly
- As the impeller wears on a pump, the pump efficiency will decrease



Let's Build a Centrifugal Pump

- Now we need a shaft to support and turn the impeller
  - It must maintain the impeller in precisely the right place
  - But that ruggedness does not protect the shaft from the corrosive or abrasive effects of the liquid pumped, so we must protect it with sleeves slid on from either end.

Shaft and Sleeves

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect shaft from wear from packing rings
  - Generally they are bronze, but various other alloys, ceramics, glass or even rubber-coating are sometimes required.

Let's Build a Centrifugal Pump

- We mount the shaft on sleeve, ball or roller bearings
  - If bearings supporting the turning shaft and impeller are allowed to wear excessively and lower the turning units within a pump's closely fitted mechanism, the life and efficiency of that pump will be seriously threatened.
  - 2 types:
    - Oil-lubricated
    - Grease lubricated

Bearings

- Anti-friction devices for supporting and guiding pump and motor shafts
- Get noisy as they wear out
- If pump bearings are over lubricated, the bearings will overheat and can be damaged or fail
  - Tiny indentations high on the shoulder of a bearing or race is called brinelling
  - When greasing a bearing on an electric motor, the relief plug should be removed and replaced after the motor has run for a few minutes. This prevents you from damaging the seals of the bearing.
- Types: ball, roller, sleeve

Bearings

- Inspect and lubricate bearings-grease
  - If possible, remove bearing cover and visually inspect grease.
  - When greasing, remove relief plug and cautiously add 5 or 6 strokes of the grease gun.
  - Afterward, check bearing temperature with thermometer.
    - If over 220°F (104°C), remove some grease.

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Let's Build a Centrifugal Pump

- To connect with the motor, we add a coupling flange
  - Our pump is driven by a separate motor, and we attach a flange to one end of the shaft through which bolts will connect with the motor flange
  - If shafts are met at an angle, every rotation throws tremendous extra load on bearings of both pump and the motor
    - Flexible couplings will not correct this condition if excessive

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Common Pump & Motor Connections

- Direct coupling
- Angle drive
- Belt or chain
- Flexible coupling
- Close-coupled

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Couplings

- Connect pump and motor shafts
- Lubricated require greasing at 6 month intervals
- Dry has rubber or elastomeric membrane

- Calipers and thickness gauges can be used to check alignment on flexible couplings

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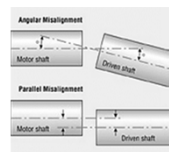
Misalignment of Pump & Motor

- Excessive bearing loading
- Shaft bending
- Premature bearing failure
- Shaft damage



- Checking alignment should be a regular procedure in pump maintenance.
  - Foundations can settle unevenly
  - Piping can change pump position
  - Bolts can loosen
  - Misalignment is a major cause of pump and coupling wear.

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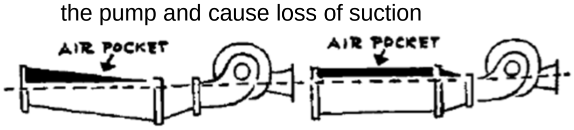
Let's Build a Centrifugal Pump

- Now we need a "straw" through which liquid can be sucked
  - Insure that the pipe does not put strain on the pump's casing
  - The horizontal pipe slopes upward toward the pump so that air pockets won't be drawn into the pump and cause loss of suction



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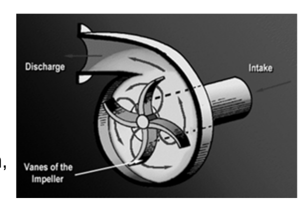
Let's Build a Centrifugal Pump

- We contain and direct the spinning liquid with a casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



Let's Build a Centrifugal Pump

- Now our pump is almost complete, but it would leak like a sieve
  - As water is drawn into the spinning impeller, centrifugal force causes it to flow outward, building up high pressure at the outside of the pump (which will force water out) and creating low pressure at the center of the pump (which will draw water in)
    - Water tends to be drawn back from pressure to suction through the space between the impeller and casing – this needs to be plugged

Let's Build a Centrifugal Pump

- So we add wearing rings (aka wear rings) to plug internal liquid leakage
  - Restrict flow between impeller discharge and suction
  - Leakage reduces pump efficiency
  - Installed to protect the impeller and pump casing from excessive wear
  - Provides a replaceable wearing surface
  - Inspect regularly

Let's Build a Centrifugal Pump

- To keep air from being drawn in, we use stuffing boxes
  - We have two good reasons for wanting to keep air out of our pump
    - We want to pump water, not air
    - Air leakage is apt to cause our pump to lose suction
  - Each stuffing box we use consists of a casing, rings of packing and a gland at the outside end
    - A mechanical seal may be used instead

Stuffing Box

- Parts include:
  - Packing
  - Lantern ring
  - Gland follower

Packing vs. Mechanical Seals

- If a pump has packing, water should drip slowly

- If it has a mechanical seal, no leakage should occur

Packing Rings

- Asbestos or metal ring lubricated with Teflon or graphite
- Provides a seal where the shaft passes through the pump casing in order to keep air form being drawn or sucked into the pump and/or the water being pumped from coming out

Packing Rings

- If new packing leaks, stop the motor and repack the pump
- Pumps need new packing when the gland or follower is pulled all the way down
- The packing around the shaft should be tightened slowly, over a period of **several hours** to just enough to allow an occasional drop of liquid (**20-60 drops per minute** is desired)
  - Leakage acts as a lubricant
- Stagger joints 180º if only 2 rings are in stuffing box, space at 120º for 3 rings or **90º if 4 rings or more are in set**

Packing Rings

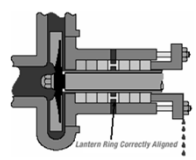
- If packing is not maintained properly, the following troubles can arise:
  - **Loss of suction** due to air being allowed to enter pump
  - **Shaft or shaft sleeve damage**
  - Water or wastewater **contaminating bearings**
  - **Flooding** of pump station
  - Rust corrosion and unsightliness of pump and area

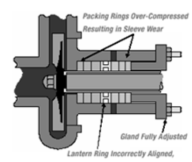
Packing Rings vs. Mechanical Seal

- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

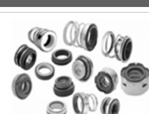
Lantern Rings

- Perforated ring placed in stuffing box
- A spacer ring in the packing gland that forms seal around shaft, helps keep air from entering the pump and lubricates packing





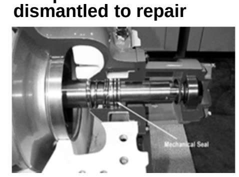
Mechanical Seals

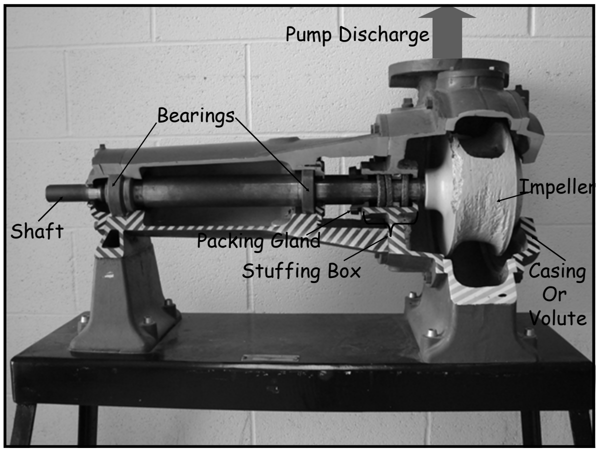


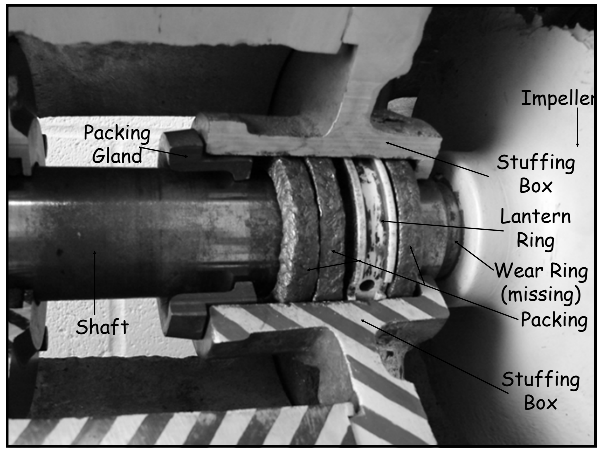
- Located in stuffing box
- Prevents water from leaking along shaft; keeps air out of pump
- **Should not leak**
- Consists of a rotating ring and stationary element
- The operating temperature on a mechanical seal should never exceed 160ºF (71ºC)
- Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear
  - The flushing water pressure in a water-lubricated wastewater pump should be **3-5 psi higher** than the pump discharge pressure.

Mechanical Seal vs. Packing Rings

- Advantages
  - **Last 3-4 years**, which can be a savings in labor
  - Usually there is **no damage to shaft sleeve**
  - **Continual adjusting, cleaning or repacking is not required**
  - Possibility of flooding lift station because a pump has thrown its packing is eliminated; however mechanical seals can fail and lift stations can be flooded
- Disadvantages
  - **High initial cost**
  - **Great skill and care needed to replace**
  - When they fail, the pump must be shut down
  - **Pump must be dismantled to repair**







Centrifugal Pump Operation

- Pump Starting -
  - Impeller must be submerged for a pump to start
    - Should never be run empty, except momentarily, because parts lubricated by water would be damaged
  - Foot valve helps hold prime
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve may close before pump stops

Centrifugal Pump Operation

- Pump shut down for extended period of time -
  - Close the valve in the suction line
  - Close the valve in the discharge line
  - Drain the pump casing

Flow Control

- Flow usually controlled by starting and stopping pumps
- Throttling flow should be avoided - wastes energy
- Variable speed drives or motor are best way to vary flow
  - Variable speed pumping equipment can be adjusted to match the inflow rate

Monitoring Operational Variables

- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

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Monitoring Operational Variables

- Suction and Discharge Heads
  - Pressure gauges
- Bearing and Motor Temperature
  - Temp indicators can shut down pump if temp gets too high
  - Check temp of motor by feel

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Monitoring Operational Variables

- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds

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Monitoring Operational Variables

- Likely causes of vibration
  - Bad bearings or bearing failure
  - Imbalance of rotating elements, damage to impeller
  - Misalignment from shifts in underlying foundation
  - Improper motor to pump alignment

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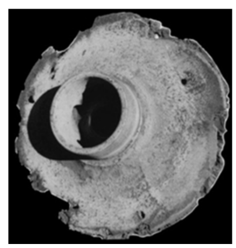
Monitoring Operational Variables



- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

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Monitoring Operational Variables

- Cavitation is a noise coming from a centrifugal pump that sounds like marbles trapped in the volute
- A condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound
- Best method to prevent it from occurring is to reduce the suction lift

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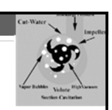
Suction Cavitation



- Suction Cavitation occurs when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapor at the eye of the pump impeller.
- This vapor is carried over to the discharge side of the pump where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure.
- This imploding action occurs violently and attacks the face of the impeller.
- An impeller that has been operating under a suction cavitation condition has large chunks of material removed from its face causing premature failure of the pump.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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Discharge Cavitation

- Discharge Cavitation occurs when the pump discharge is extremely high.
- It normally occurs in a pump that is running at less than 10% of its best efficiency point.
- The high discharge pressure causes the majority of the fluid to circulate inside the pump instead of being allowed to flow out the discharge.
- As the liquid flows around the impeller it must pass through the small clearance between the impeller and the pump cutwater at extremely high velocity.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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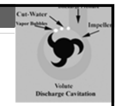

Discharge Cavitation

- This velocity causes a vacuum to develop at the cutwater similar to what occurs in a venturi and turns the liquid into a vapor.
- A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump cutwater.
- In addition due to the high pressure condition premature failure of the pump mechanical seal and bearings can be expected and under extreme conditions will break the impeller shaft.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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Inspection and Maintenance

- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler gauge, dial indicator calipers are tools that can be used to check proper alignment
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

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Inspection: Impellers

- Wear on impeller and volute
- Cavitation marks
- Chips, broken tips, corrosion, unusual wear
- Tightness on shaft
- Clearances
- Tears or bubbles (if rubber coated)

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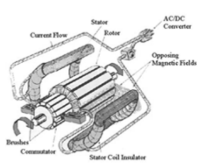
Pump Won't Start?



- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open

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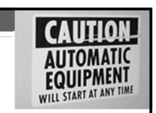
Pump Safety



- Machinery should always be turned off and locked out/tagged out before any work is performed on it
- Make sure all moving parts are free to move and all guards in place before restarting
- Machinery creating excessive noise shall be equipped with mufflers.

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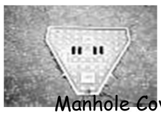
Pump Safety: Wet Wells

- Confined spaces
- Corrosion of ladder rungs
- Explosive atmospheres
- Hydrogen sulfide accumulation
- Slippery surfaces



Manhole Cover, London

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Pump Facts

- Sewer pumps used in a lift station shall be capable of passing at least a 3 inch diameter sphere
- Pump suction and discharge opening shall be no less 4 inches in diameter
- Each pump must have its own intake line
- Wet wells should be designed to avoid turbulence near the intakes
- The velocity in the suction line of a pump should not exceed 6 fps
- The velocity in the discharge line of a pump should not exceed 8 fps

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Pump Facts

- Ventilation in wet wells shall provide for at least 12 complete air changes per hour if continuous and 30 changes per hour if intermittent
- Ventilation in dry wells shall provide for at least 6 complete air changes per hour if continuous and 30 changes per hour if intermittent

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Pump Facts

- The maximum recommended suction lift for a pump in a pumping station is 15 feet
- Minimum force main size is 4 inches
- A gasoline powered centrifugal pump in good condition can lift water (suction lift) up to 18 inches of mercury
  - 20 feet of possible suction lift
- Head is the amount of energy possessed by water at any point in a hydraulic system
  - Feet divided by 2.31 equals psi (pounds per square inch) in head

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Types of Pumps Found in Collection Systems

- Incline screw pump
- Centrifugal
- Pneumatic ejectors
- Piston
- Close-coupled
- Submersible
- Progress cavity
- Flexible stator and rotor

Pump Vocabulary

1. Axial-Flow Pump – a pump in which a propeller-like impeller forces water out in the direction parallel to the shaft. Also called a propeller pump.
2. Bearing – anti-friction device used to support and guide a pump and motor shafts.
3. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
4. Cavitation – a condition that can occur when pumps are run too fast or water is forced to change direction quickly. A partial vacuum forms near the pipe wall or impeller blade causing potentially rapid pitting of the metal.
5. Centrifugal Pumps – a pump consisting of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at high velocity, and the casing shape converts this velocity to pressure.
6. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
7. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
8. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
9. Foot Valve – a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end. Keeps prime.
10. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
11. Impeller – the rotating set of vanes that forces water through the pump.
12. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
13. Lantern Ring – a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.
14. Mechanical Seal – a seal placed on the pump shaft to prevent water from leaking from the pump along the shaft; the seal also prevents air from entering the pump.
15. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
16. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
17. Packing Gland – a follower ring that compressed the packing in the stuffing box.
18. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.

19. Prime Mover – a source of power, such as an internal combustion engine or an electric motor, designed to supply force and motion to drive machinery, such as a pump.
20. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
21. Reciprocating Pump – a type of positive-displacement pump consisting of a closed cylinder containing a piston or plunger to draw liquid into the cylinder through an inlet valve and forces it out through an outlet valve.
22. Rotary Pump – a type of positive-displacement pump consisting of elements resembling gears that rotate in a close-fitting pump case. The rotation of these elements alternately draws in and discharges the water being pumped.
23. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
24. Stuffing Box – a portion of the pump casing through which the shaft extends and in which packing or a mechanical seal is placed to prevent leakage.
25. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
26. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
27. Velocity Pump – the general class of pumps that use a rapidly turning impeller to impart kinetic energy or velocity to fluids. The pump casing then converts this velocity head, in part, to pressure head. Also known as kinetic pumps.
28. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
29. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head..
30. Water Hammer – the potentially damaging slam that occurs in a pipe when a sudden change in water velocity (usually as a result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
31. Wear Rings – rings made of brass or bronze placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

Pump and Motor Review Questions

1. Leakage of water around the packing on a centrifugal pump is important because it acts as a (n):
   a. Adhesive
   b. Lubricant
   c. Absorbent
   d. Backflow preventer

2. What is the purpose of wear rings in a pump?
   a. Hold the shaft in place
   b. Hold the impeller in place
   c. Control amount of water leaking from discharge to suction side
   d. Prevent oil from getting into the casing of the pump

3. Which of the following does a lantern ring accomplish?
   a. Lubricates the packing
   b. Helps keep air from entering the pump
   c. Both (a.) and (b.)

4. Closed, open and semi-open are types of what pump part?
   a. Impeller
   b. Shaft sleeve
   c. Casing
   d. Coupling

5. When tightening the packing on a centrifugal pump, which of the following applies?
   a. Tighten hand tight, never use a wrench
   b. Tighten to 20 foot pounds of pressure
   c. Tighten slowly, over a period of several hours
   d. Tighten until no leakage can be seen from the shaft

6. Excessive vibrations in a pump can be caused by:
   a. Bearing failure
   b. Damage to the impeller
   c. Misalignment of the pump shaft and motor
   d. All of the above

7. What component can be installed on a pump to hold the prime?
   a. Toe valve
   b. Foot valve
   c. Prime valve
   d. Casing valve

8. The operating temperature of a mechanical seal should not exceed:
   a. 60°C
   b. 150°F
   c. 160°F
   d. 71°C
   e. c and d

9. What is the term for the condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound?
   a. Corrosion
   b. Cavitation
   c. Aeration
   d. Combustion

10. The first thing that should be done before any work is begun on a pump or electrical motor is:
    a. Notify the state
    b. Put on safety goggles
    c. Lock out the power source and tag it
    d. Have a competent person to supervise the work

11. Under what operating condition do electric motors pull the most current?
    a. At start up
    b. At full operating speed
    c. At shut down
    d. When locked out

12. As the impeller on a pump becomes worn, the pump efficiency will:
    a. Decrease
    b. Increase
    c. Stay the same

13. How do the two basic parts of a velocity pump operate?

14. What are two designs used to change high velocity to high pressure in a pump?

15. In what type of pump are centrifugal force and the lifting action of the impeller vanes combined to develop the total dynamic head?

16. Identify one unique safety advantage that velocity pumps have over positive-displacement pumps.

17. What is the multistage centrifugal pump? What effects does the design have on discharge pressure and flow volume?

18. What are two types of vertical turbine pump, as distinguished by pump and motor arrangement, which are commonly used to pump ground water from wells?

19. What type of vertical turbine pump is commonly used as an inline booster pump?

20. Describe the two main parts of a jet pump.

21. What is the most common used of positive-displacement pumps in water plants today?

22. What is the purpose of the foot valve on a centrifugal pump?

23. How is the casing of a double-suction pump disassembled?

24. What is the function of wear rings in centrifugal pumps of the closed-impeller design? What is the function of the lantern rings?

25. Describe the two common types of seals used to control leakage between the pump shaft and the casing.

26. What feature distinguishes a close-coupled pump and motor?

27. What is the value of listening to a pump or laying a hand on the unit as it operates?

28. Define the term “racking” as applied to pump and motor control.

29. When do most electric motors take the most current?

30. What are three major ways of reducing power costs where electric motors are used?

31. What effect could over lubrication of motor bearings have?

32. Why should emery cloth not be used around electrical machines?

33. What are the most likely causes of vibration in an existing pump installation?

34. What can happen when a fuse blows on a single leg of a three-phase circuit?

35. Name at least three common fuels for internal-combustion engines.

36. List the type of information that should be recorded on a basic data card for pumping equipment.

37. What is the first rule of safety when repairing electrical devices?

Answers:

1. B	4. A	7. B	10. C
2. C	5. C	8. E	11. A
3. C	6. D	9. B	12. A

13. A spinning impeller accelerates water to a high velocity within a casing, which changes the high-velocity, low-pressure water to a low-velocity, high-pressure discharge.
14. Volute casing and diffuser vanes.
15. Mixed-flow pump (the design used for most vertical turbine pumps)
16. If a valve is closed in the discharge line, the pump impeller can continue to rotate for a time without pumping water or damaging the pump.

17. A multistage centrifugal pump is made up of a series of impellers and casings (housings) arranged in layers, or stages. This increases the pressure at the discharge outlet, but does not increase flow volume.
18. Shaft-type and submersible-type vertical turbines.
19. A close-coupled vertical turbine with an integral sump or pot.
20. The jet pump consists of a centrifugal pump at the ground surface and an ejector nozzle below the water level.
21. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
22. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
23. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
24. Wear rings prevent excessive circulation of water between the impeller discharge and suction area. Lantern rings allow sealing water to be fed into the stuffing box.
25. (1) Packing rings are made of graphite-impregnated cotton, flax, or synthetic materials. They are inserted in the stuffing box and held snuggly against the shaft by an adjustable packing gland. (2) Mechanical seals consist of two machined and polished surfaces. One is attached to the shaft, the other to the casing. Spring pressure maintains contact between the two surfaces.
26. The pump impeller is mounted directly on the shaft of the motor.
27. An experienced operator can often detect unusual vibration by simply listening or touching. Vibration, especially changes in vibration level, are viewed as symptoms or indicators of other underlying problems in foundation, alignment and/or pump wear.
28. Racking refers to erratic operation that may result from pressure surges when the pump starts; it is often a problem when the pressure sensor for the pump control is located too close to the pump station.
29. During start-up.
30. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
31. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
32. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
33. Imbalance of the rotating elements, bad bearings and misalignment
34. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.
35. gasoline, propane, methane, natural gas and diesel oil (diesel fuel)
36. make, model, capacity, type, date and location installed, and other information for both the driver (motor) and the driven unit (pump)
37. Make sure the power to the device is disconnected. This is critical since rubber gloves, insulated tools and other protective gear are not guarantees against electrical shock.

Section 11

Equipment Maintenance

Equipment Maintenance

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Beware of Electricity

- Be careful around electrical panels, circuits, wiring, & equipment
  - Serious injury
  - Damage costly equipment
- Basic working knowledge is key

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Tools, Meters & Testers

- Ammeter: records the current or amps in circuit
  - Most are clamp on type

- Megger: checks insulation resistance on motors, feeders, grounds, and branch circuit wiring
  - Motors should be megged at least once a year

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Tools, Meters & Testers

- Ohmmeter: measures resistance in a circuit.
  - An ohmmeter is used only when the electric circuit is off or de-energized
  - Tests fuses, relays, resistors and switches.

- Multimeter: checks for voltage
  - By holding one lead on ground and the other on a power lead, you can determine if power is available
  - You can also tell if it is AC or DC and the intensity or voltage (110, 220, 480 or whatever) by testing the different leads

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Need for Maintenance

- Performance and life of pumps and other equipment affected by:
  - Water
  - Dust
  - Humidity
  - Heat and cold
  - Vibration
  - Corrosive atmosphere

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Need for Maintenance

- Inspect & maintain electrical equipment annually.
- Inspection should include:
  - Thorough examination
  - Replacement of worn & expendable parts
  - Operational checks & tests
- Fuses and circuit breakers are protective devices used to protect operators, main circuits, branch circuits, heater, motors and various other electrical equipment.

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Electrical Protective Devices: Fuses

- Protect control panel from excess voltage or amperage
- Fusible metal strip melts and breaks circuit
- One-time use devices
  - Should never be jumped or bypassed
  - When removing any fuse, a fuse puller should be used

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Electrical Protective Devices: Circuit Breaker

- Protect electrical systems from short circuiting
- Switch opens when current or voltage out of range
- Unlike fuse, can be reset

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Transformer

- Allows energy to be transferred in an AC system for one circuit to another
- Used to convert high voltage to low voltage
  - High voltage is 440 volts or higher
- Standby engines should be run weekly to ensure that it is working properly
- Relays are used to protect electric motors

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- Converters
  - Sometimes used to change the frequency in an AC power system
- Rectifiers
  - Changes AC to DC by allowing the current to flow in one direction only
- Inverters
  - Changes DC to AC

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D.C. versus A.C.

- Direct current (D.C.) is flowing in one direction only and is essentially free from pulsation
  - DC is seldom used in lift stations and wastewater treatment plants except in motor-generated sets, some control components of pump drives and standby lighting
  - DC is used exclusively in automotive equipment, certain types of welding equipment, and a variety of portable equipment
  - All batteries are DC
- Alternating current (A.C.) is periodic current that has alternating positive and negative values
  - AC are classified as:
    - Single phase
    - Two phase
    - Three phase or polyphase

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Batteries

- An electric battery is a device for the transformation of chemical energy into electric energy
- A primary battery is a battery that the chemical action is irreversible, like a flashlight battery
- A storage battery is one that the chemical action is almost completely reversible, like a car battery
- The most common battery is the lead-acid type
- Another common type of battery is the nickel-cadmium type

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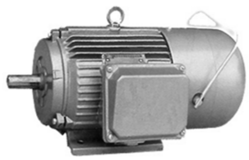
A.C. Induction Motor

- Most common pump driver in wastewater pump stations
- Motors pull the most current on start up.
- Malfunction due to:
  - Thermal overload (40°C max.)
  - Contaminants
  - Single phasing
  - Old age
  - Rotor failure



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Single-phase vs Three-phase

- Single-phase power is found in lighting systems, small pump motors, variable portable tools and throughout our homes.
  - It is usually 120 volts or 240 volts
  - Single phase means only one phase of power is supplied to the main electrical panel at 240 volts and the power supply has three wires or leads
    - 2 of these leads have 120 volts each, the other lead is neutral and usually coded white, which is grounded
- Three-phase power is generally used with motors and transformers found in lift stations and wastewater treatment plants
  - Generally all motors above 2 horsepower are three-phase

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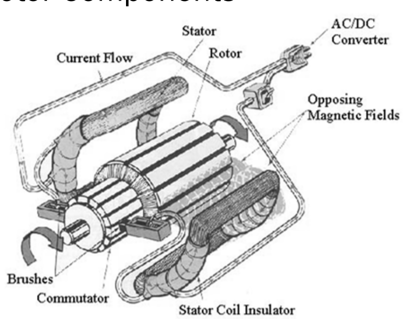
Motor Components



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Motors

- In order to prevent damage, turn the circuit off immediately if the fuse on one of the legs of a three-phase circuit blows.
- An electric motor changes electrical energy into mechanical energy
- Power factors can be improved by:
  - Changing motor loading
  - Changing the motor type
  - Using capacitors
    - Also referred to as a condenser and it will also store electricity when it is charged

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Motors

- Routine cleaning of pump motors includes:
  - Checking alignment and balance
  - Checking brushes
  - Removing dirt and moisture
  - Removal of obstructions that prevent air circulation
- Cool air extends the useful life of motors
- A motor (electrical or internal combustion) used to drive a pump is called a prime mover
- The speed at which the magnetic field rotates is called the motor synchronous speed and is expressed in rpm

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Motors

- If a variable speed belt drive is not used for 30 days or more, shift the unit to minimum speed setting
- Emory cloth should not be used on electric motor components because it is electronically conductive and may contaminate parts
- Ohmmeters used to test a fuse in a motor starter circuit
- The most likely cause of a three-phase motor not coming to speed after starting – the motor has lost power to one or more phases

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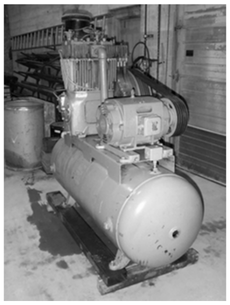
Compressors



- Increase the pressure of air or gas
- Common uses:
  - Wastewater ejectors
  - Pump control systems (bubblers)
  - Water pressure systems
  - Portable pneumatic tools

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Compressors

- Inspect suction filter at least monthly
  - Daily in dusty areas such as construction zones
- Inspect safety valves weekly
- Lubrication
  - Oil bearings
  - Oil cup, grease fittings, crankcase reservoir
  - Change oil every 3 months (unless otherwise specified)
- Inspect belt tension
- Clean dirt, oil & grease at least monthly
- Drain condensate daily using valve on air receiver
- Examine operating controls

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Valves

- Controlling device in piping systems to stop, regulate, check, or divert flow of liquids or gases
- Types of valves found in a pumping station
  - Butterfly – used on suction and discharge
  - Gate – used on suction and discharge
  - Plug – used on suction and discharge
  - Swing or ball check – used on discharge
  - Knife – used on suction and discharge
  - Wafer – used on discharge

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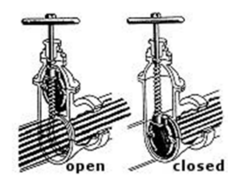
Valves

- Gate valve:
  - Open valve fully; reverse & close one-half turn
  - Operate all large valves at least yearly
  - Inspect valve stem packing for leaks; tighten if needed
  - Close valves slowly in pressure lines to prevent water hammer



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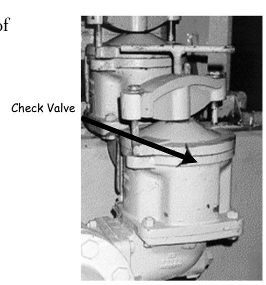
Valves

- Check valves: discharge of pump to provide positive shut off from force main pressure & prevent force main from draining back into wet well



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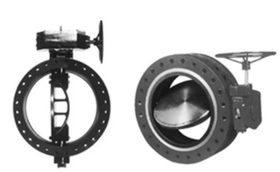
Valves

- Butterfly valves: often clog on sewer lines when installed to carry stormwater or wastewater
- Plug valves: less susceptible to plugging; sludge pumping



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Lubrication

- Purposes:
  - Reduce friction between two surfaces
  - Remove heat due to friction
- Oils in service becomes acidic & may cause corrosion, deposits, sludging, etc.
- Oils & greases:
  - Can create fire hazard
  - Clean up spills immediately
  - Don't contaminate

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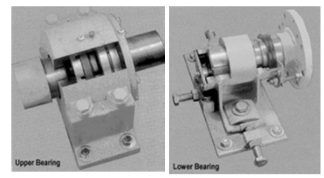
Bearings

- Screw pumps are supported by 2 bearings, a ball or roller bearing above the flights & a sleeve bearing in the WW



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Bearings

- Usually last for years if serviced properly
- Failures:
  - Fatigue – excessive load
  - Contamination
  - Brinelling – improper mounting
  - Electric arching – leakage; short circuiting
  - Misalignment
  - Cam failure
  - Lubrication failure – dirty; too much; not enough; wrong kind

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Building Maintenance

- Only one person should be in charge on any maintenance program.
- Keep facility clean, store tools in proper place
- Type of maintenance needed influenced by age, type & use of building
- Maintenance program includes:
  - Floors & roofs
  - Heating, cooling & ventilation
  - Lighting
  - Plumbing
  - Windows

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Equipment Maintenance Vocabulary

______1. Amperage
______2. Brinelling
______3. Cavitation
______4. Circuit
______5. Circuit Breaker
______6. Current
______7. Fuse
______8. Jogging
______9. Mandrel
______10. Megger
______11. Resistance
______12. Voltage

A. A safety device in an electric circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.
B. Tiny indentations (dents) high on the shoulder of the bearing race or bearing. A type of bearing failure.
C. A special tool used to push bearing in or to pull sleeves out. Also can be a gage used to measure for excessive deflection in a flexible conduit.
D. A protective device having a strip or wire of fusible metal that, when placed in a circuit, will melt and break the electric circuit if heated too much. High temperatures will develop in the fuse when a current flows through the fuse in excess of that which the circuit will carry safely.
E. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. This is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.
F. The electrical pressure available to cause a flow of current (amperage) when an electric circuit is closed.
G. The frequent starting and stopping of an electric motor.
H. A movement or flow of electricity.
I. An instrument used for checking the insulation resistance on motors, feeders, bus bar systems, grounds and branch circuit wiring.
J. The strength of an electric current measured in amperes. The amount of electric current flow, similar to the flow of water in gallons per minute.
K. That property of a conductor or wire that opposes the passage of a current, thus causing electrical energy to be transformed into heat.
L. The complete path of en electric current, including the generating apparatus or other source; or, a specific segment or section of the complete path.

Equipment Maintenance Questions

1. What are some of the uses of a voltage tester?

2. How often should motors and wirings be megged?

3. An ohmmeter is used to check the ohms of resistance in what control circuit components?

4. What are the two types of safety devices found in main electrical panels or control units?

5. What is the most common pump driver used in lift stations?

6. Why should inexperienced, unqualified or unauthorized persons and even qualified and authorized persons be extremely careful around electrical panels, circuits, wiring and equipment?

7. Under what conditions would you recommend the installation of a screw pump?

8. What are the advantages of a pneumatic ejector?

9. What is the purpose of packing?

10. What is the purpose of the lantern ring?

11. How often should impellers be inspected for wear?

12. What is the purpose of wear rings?

13. What causes cavitation?

14. How often should the suction filter of a compressor be cleaned?

15. How often should the condensate from the air receiver be drained?

16. What is the purpose of lubrication?

17. What precautions must be taken before oiling or greasing equipment?

18. If an ammeter reads higher than expected, the high current could produce
    a. “Freezing” of motor windings
    b. Irregular meter readings
    c. Lower than expected output horsepower
    d. Overheating and damage equipment

19. The <u>greatest cause</u> of electric motor failures is
    a. Bearing failures
    b. Contaminants
    c. Overload (thermal)
    d. Single phasing

20. Flexible shafting is used where the pump and driver are
    a. Coupled with belts
    b. Difficult to keep properly aligned
    c. Located relatively far apart
    d. Required to be coupled with universal joints

21. Never operate a compressor without the suction filter because dirt and foreign materials will cause
    a. Deterioration of lubricants
    b. Effluent contamination
    c. Excessive water
    d. Plugging of the rotors, pistons or blades

Answers to Vocabulary and Questions

Vocabulary:

1. J	5. A	9. C
2. B	6. H	10. I
3. E	7. D	11. K
4. L	8. G	12. F

Questions:

1. A voltage tester can be used to test for voltage, open circuits, blown fuses, single phasing of motors and grounds.
2. At least once a year and twice a year if possible
3. Coils, fuses, relays, resistors and switches
4. Fuses and circuit breakers
5. A.C. induction motor
6. You can seriously injure yourself or damage costly equipment.
7. To pump fluctuating flows with large solids and rags.
8. They can handle limited flows with relatively large solids. Maintenance is not as complicated as the maintenance on most pumps; however, maintenance must be performed when scheduled.
9. To keep air from leaking in and water leaking out where the shaft passes through the casing

10. To allow outside water or grease to enter the packing for lubrication, flushing, and cooling and to prevent air from being sucked or drawn into the pump
11. Every 6 months or annually, depending on pumping conditions; if grit, sand or other abrasive material is being pumped, inspections should be more frequent
12. They protect the impeller and pump body from damage due to excessive wear.
13. Cavitation can be caused by a pump operating under different conditions than what it was designed for, such as off the design curve, poor suction conditions, high speed, air leaks into suction end and water hammer conditions.
14. The frequency of cleaning a suction filter on a compressor depends on the use of a compressor and the atmosphere around it. The filter should be inspected at least monthly and cleaned or replaced every three to six months. More frequent inspections, cleanings and replacements are required under dusty conditions such as operating a jackhammer on a street.
15. Daily
16. To reduce friction between two surfaces and to remove heat caused by friction
17. Shut it off, lock it out and tag it so it can't be started unexpectedly and injure you
18. D
19. C
20. C
21. C

Section 12

Underground Repair

Underground Repair of Sewers

- Safety Considerations
- Sources of Damages & Stoppages
- Grouting
- Manhole Problems

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Safety Considerations

- Cave-ins
  - Underground repair to replace damaged pipe or remove obstruction may require use of trench shield
- Dangerous gases & fumes, explosive conditions, lack of oxygen
- Traffic
  - Repairs in roadways require traffic control.
- Injury
- Public & private property
- Public from injury

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Types of Underground Work

- Correct damage
- Remove obstructions preventing proper functioning of sewer
- Retrieve equipment stuck in the line

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Sources of Damages & Stoppages

- Roots
- Improper taps
- Damage by public (illegal taps or vandalism)
- Other underground construction

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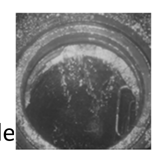
Grout Sealing



- Area unsuitable for excavation
- Infiltrating or exfiltrating through le cracks or small holes
- New construction to pass test acceptance
- Grout is commonly used to seal leaking joints and circumferential cracks, not collapsed pipe sections or broken pipes.

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Universal Grouting Applications

- Mainlines and Pipe Joints
- Lateral Sealing
- Manholes, Wet Wells and Lift Stations
- Soil Stabilization

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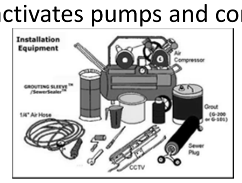
Grouting Materials

- Hydrophilic foams
- Hydrophilic gels
- Hydrophobic foams
- Chemically activated gels
- Epoxies
- Acrylamide
- Acrylate
- Urethane
- Cementitious

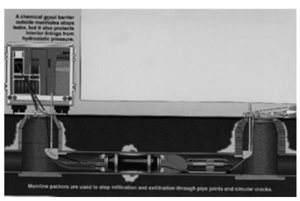
Basic Grouting Equipment

- Air compressor- operates pumps and inflates packer
- Chemical pump
- Water pump
- Control panel- activates pumps and controls packer
- Sleeve packer

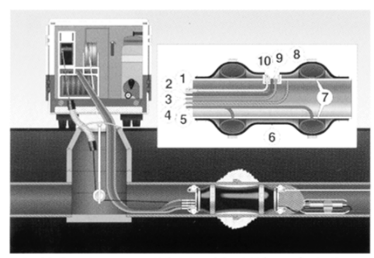


Sealing Process

- TV camera faces packer to observe operation.
- TV camera downstream of packer.
- Roots in sewer and joints killed & removed prior to using root control chemicals.



Detail of Sleeve Packer



Modern injection packers are very sophisticated, consisting of; (1) Pressure Sensing Line, (2) Chemical "A" Line, (3) Chemical "B" and Air Pressure Line, (4) Sleeve Air Line, (5) End Seal Air Line, (6) Sleeve, (7) End Seal Elements, (8) Sealing Pads, (9) Chemical Injection Ports, (10) Pressure Sensor Element.

Grouting

Desirable Grout Characteristics

- Resistant to organic solvents, mild acids and alkalis
- Returns to shape after deformation
- Nontoxic when cured
- Not rigid or brittle when exposed to freeze-thaw or dry conditions
- Non corrosive; no neurotoxin ingredients

Grout Limitations

- Not a structural repair
- Must thoroughly clean pipe/manhole first
- Packer won't seal properly in badly corroded pipe
- Not permanent
- Some dehydrate & shrink if groundwater level drops

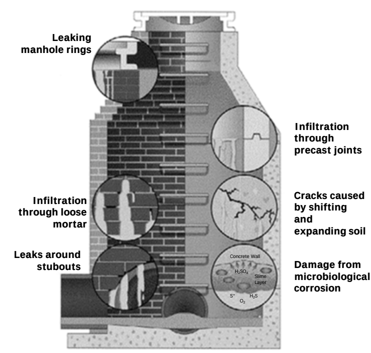
Factors that Effect Grout Performance

- Temperature
- pH
- Entrained oxygen in solution
- Contact with metals
- UV light
- Velocity of groundwater flows
- Mineral salts
- Proper use of equipment & process

Chemical Grout Additives

- Latex/emulsion/reinforcing agent: increases compression and tensile strength
- Accelerators: speeds up gel time (urethanes)
- Dichlobenil: inhibits root growth
- Tracer dye: illustrates proper mixing and travel
- Ethylene glycol: protects against freezing or drying out
- KFe Potassium Ferricynaide: extends gel time (acrylamide & acrylate)

Manhole Problems



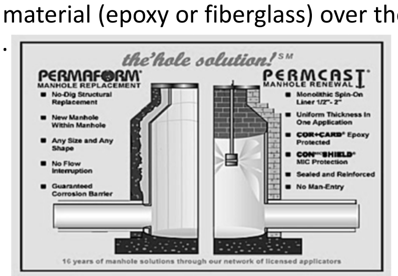
Repair Leaking Barrels

- Patching using fast dry cement.
- Grouting by hand or with sprays.
- Lining with spray-on epoxy or fiberglass or insert liner.

Grout is pumped into the soil outside the manhole. This keeps water from entering at the damaged area.

Manhole Liner

- Lining manhole by inserting liner or spraying a lining material (epoxy or fiberglass) over the barrel.



Manhole Liner

- Badly corroded brick manhole.
  - Prior to lining, surface must be cleaned with high pressure water to remove grease, sludge, mineral deposits, and loose brick and mortar.
- For larger manholes or wet wells, liner may be sprayed on by operator in the structure rather than from ground level.

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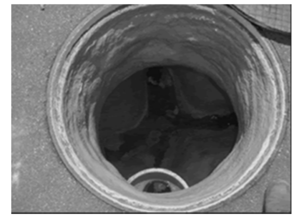
Manhole Liner

Before

After



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Air Testing

- The main reason for using low-pressure air testing for testing sewers is that pressurized air exerts the same pressure in all directions on the pipe during a specific moment in time
- The fact that air can leak through a smaller crack than wastewater helps find vapor leaks that may attract roots.
- Also, air could leak out of a small crack that could become a large crack in the future

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Water Testing

- Where conditions are appropriate, a water exfiltration test will provide an accurate test of a new sewer line’s ability to convey wastewater without excess leakage and to resist groundwater infiltration
  - Any building sewer connections must be plugged

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Underground Repair Vocabulary

______1. Angle of Repose
______2. Annular
______3. Cross Braces
______4. Gunite
______5. Hydrophilic
______6. Hydrophobic
______7. Sheeting
______8. Spoil
______9. Stringers
______10. Vacuum Test

A. Having a strong affinity (liking) to water.
B. Solid material, such as wooden 2-inch planks or $1^1/_8$ –inch plywood sheets or metal plates, used to hold back soil and prevent cave-ins.
C. The angle between a horizontal line and the slope or surface of unsupported material such as gravel, sand or loose soil. Also called the "natural slope."
D. Horizontal shoring members, usually square, rough cut timber, that are used to hold solid sheeting, braces or vertical shoring members in place. Also called wallers.
E. Shoring members placed across a trench to hold other horizontal and vertical shoring members in place.
F. Excavated material such as soil from the trench of a sewer.
G. Having a strong aversion (dislike) for water.
H. A testing procedure that places a manhole under a vacuum to test the structural integrity of the manhole.
I. A ring-shaped space located between two circular objects. For example, the space between the outside of a pipe liner and the inside of a pipe.
J. A mixture of sand and cement applied pneumatically that forms a high-density, resistance concrete.

Underground Repair Questions

1. Why might a sewer line have to be dug up?

2. Why should other utility companies be notified before any excavation?

3. Why are sewer repairs sometimes necessary?

Answers to Vocabulary and Questions

Vocabulary:

1. C
2. I
3. E
4. J
5. A
6. G
7. B
8. F
9. D
10. H

Questions:

1. Sewer lines may have to be dug up because they are damaged, blocked, or to retrieve equipment stuck in the line.
2. All utilities in an area should be contacted before excavation so other underground utilities will not be damaged and possibly cause a serious injury (from electric shock or a gas explosion) to operators, the public or property.
3. Wastewater collection system repairs are necessary to correct damage to sewer.

Section 13

Sewer Renewal (Rehab)

HDPE pipe sliplining job shown

Sewer Pipeline Rehabilitation

- Sewer System Evaluation
- Excavate and Replace
- Grouting
- Sliplining
- Cured in Place Pipe (CIPP)
- Fold and Form
- Pipe Bursting

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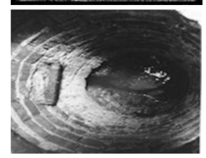
Why Rehabilitate?

- Restore structural integrity:
  - Corrosion
  - Deterioration
  - Damage from stress & live loads
- Control excess I/I during rainfall or high groundwater



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Sewer System Evaluation

- Helps reduce hydraulic load to sewer and treatment facility. I/I causes:
  - Increased treatment costs
  - Bypassing of untreated wastewater
  - Structural failure weakened collection system
- Primary tool for identifying high I/I: flow monitoring

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Techniques to Determine Sewer Condition

- CCTV: most effective method to identify & quantify defects
- Pipe flow tests
- Computer flow models
- Visual inspection
  - Smoke tests- quick, inexpensive
  - Dye testing
  - Lamping

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Excavate and Replace

- Oldest and most common method
- Corrects misalignment of pipe
- Sometimes only method if defect is severe.
- Should be considered on every job.
- Exfiltration may contaminate groundwater used as drinking water source.

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Excavate and Replace

- Same problems apply as with all new construction.
- Increases hydraulic capacity
- Repair bad service connections
- Eliminate sources of stormwater entry
- Removal incidental I/I
- Stop exfiltration

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Common Construction Problems

- Traffic disruption much longer than with other methods.
- Restoration includes paving, driveways, sidewalks, fences, landscaping.
- Often more expensive, too.
- Other issues:
  - Shoring
  - Excavation dewatering
  - Noise

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Internal Sealing

- Internal sealing is effective when the sewer line to be repaired has cracks and leaking joints

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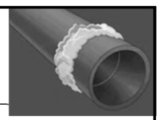
Chemical Grouting



- Most widely used method to seal leaking joints and circumferential cracks
- Remove roots and grease first
- Dig up joint or do low pressure air test to determine success of chemical grouting

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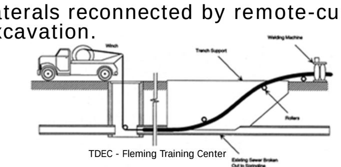
Sliplining

- New liner of smaller diameter placed inside existing pipe.
- Not completely trenchless as insertion pit must be dug.
- Continuous (shown): 40 ft sections butt-fusion welded.
  - Also segmental and spiral wound.
- Laterals reconnected by remote-cutter or excavation.



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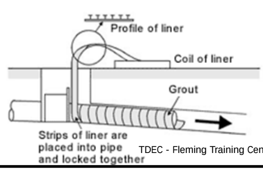
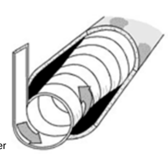
Spiral Wound Sliplining Process

- Annular space is grouted to prevent leaks and provide structural integrity
- Spiral wound pipe with interlocking edges to connect segments.





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Sliplining Features

- Insertion pit required
- Reduced pipe diameter
- Not well suited for small diameter pipes
- Requires little technical skill
- Excellent corrosion resistance

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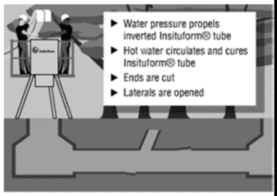
Cured-in-Place Pipe (CIPP)

- Pipe is cleaned and CCTV inspection is done
- Custom made felt tube is impregnated with thermosetting resin
- Weight of water pushes tube into damaged pipe & turns it inside out
- Laterals are cut internally



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Cured-in-Place Pipe (CIPP)

- Flexible fabric liner coated with thermosetting resin.
  - Each sock is custom made for specific job.
  - Keep ≤ 40°F and out of direct sunlight.
    - Heat may cause resin to react and begin to harden.
    - UV light deteriorates material.

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Cured-in-Place Pipe (CIPP)

- Pipe inverted with water (shown) or air.
- Laterals are reconnected with robotic cutter positioned and controlled by operator watching TV monitor
  - Laterals easily found since line was televised after cleaning and prior to start of rehab project.

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CIPP Features

- No grouting or excavation required
- New pipe has no joints or seams
- Bypass or diversion of flow required
- Must allow adequate curing time
- Small decrease in pipe diameter, but improved flow capacity due to smooth surface
- Proprietary

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Fold and Formed Pipe

- HDPE or PVC pipe is deformed in shape & inserted into host pipe
- Liner is pulled through existing line, heated and pressurized to original shape
- Bypass or diversion of flow required
- Laterals reconnected internally
- No grouting or excavation
- No joints or seams

U-Liner™

"The Leader in Trenchless Pipeline Rehabilitation"

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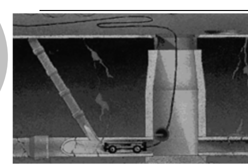
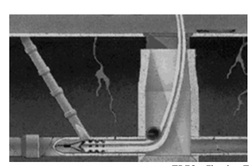
U-Liner® Installation





- Host pipe is thoroughly cleaned and inspected with CCTV.
- Pipe is uncoiled into upstream manhole and pulled through host pipe via cable from downstream manhole. Pipe is cut to the appropriate length and manifolds are attached at both ends.

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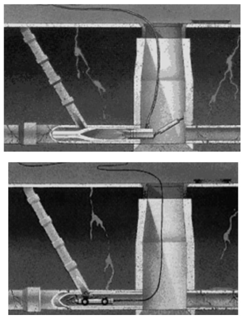
U-Liner® Installation



- Heat and pressure are applied to conform new pipe to host pipe.
- Individual service connections are restored with internal cutter. Device is remote-controlled, video monitored, and cuts precisely.

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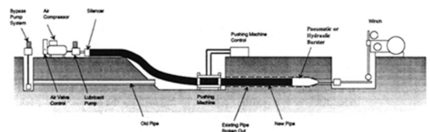
Pipe Bursting

- Insertion pit is excavated.
- Deteriorated host pipe is broken outward by means of an expansion tool and new pipe (black) is towed behind the bursting machine.
- Laterals reconnected by excavation after job is done.



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Bursting Heads

- Pneumatic (static) head has no moving internal parts and expands existing pipe through pulling.
- This model features a cutter to aid in shattering the host pipe.

Hydraulic head pulsates as the bursting device is pulled through the pipe.

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Pipe Bursting Features

- New pipe is PE, PP, PVC or GFR
- No reduction in capacity; can often upsize the new pipe
- Bypass or diversion of flow
- Insertion pit required
- Not suitable for all materials: can replace vitrified clay, cast iron, unreinforced concrete, & some PVC

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Questions???

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Sewer Renewal Vocabulary

______1. Annular
______2. Flow Isolation
______3. Infiltration
______4. Inflow
______5. Piezometer
______6. Surcharge

A. The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connection or manhole walls.
B. A ring-shaped space located between two circular objects. For example, the space between the outside of a pipe liner and the inside of a pipe.
C. The supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe and the sewer is under pressure or a head, rather than at atmospheric pressure.
D. Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage.
E. A procedure used to measure inflow and infiltration (I/I). A section of sewer is blocked off or isolated and the flow from the section is measured.
F. An instrument used to measure the pressure head in a pipe, tank or soil.

Sewer Renewal Questions

1. What causes sewers to lose their structural integrity?

2. What problems are common to all types of sewer construction?

3. Why should a lateral be lined?

4. What is the oldest and most common method of sewer rehabilitation?

5. What is the most common method of sealing leaking pipe joints and circumferential cracks?

True-False

6. Flows greater than the expected base flow can be considered to come from inflow and infiltration sources.
   True
   False

7. Smoke testing is a slow and expensive method of detecting illegal I/I sources in a sewer system.
   True
   False

Multiple Choice

8. The <u>first step</u> in defining a sewer rehabilitation program is to:
   a. Analyze condition of the system
   b. Collect flow measurement data
   c. Conduct an inventory of the system
   d. Set goals of rehabilitation program

9. Exfiltration can be a serious problem in areas where exfiltration flow can:
   a. Cause flooding of surface water
   b. Contaminate groundwater used for public drinking water supply
   c. Overload lift stations
   d. Reduce scouring velocities in sewers

10. The CIPP saturated liner should be kept:
   a. At ambient temperature until installation
   b. At or below 40° F (4° C)
   c. Out of direct sunlight
   d. Dry until installation
   e. B and C

11. When a service connection has suffered total collapse and is in a crushed condition, the service connection is restored by:
    a. Chemical grout
    b. Cured-in-place pipe
    c. Excavation and replacement
    d. Sliplining

12. When manhole walls have suffered deterioration due to hydrogen sulfide attack, they can be repaired with:
    a. Coating processes
    b. Excavation and replacement
    c. Grout
    d. Paint
    e. Sliplining

Answers to Vocabulary and Questions

Vocabulary:

1. B
2. E
3. A
4. D
5. F
6. C

Questions:

1. Due to corrosion and deterioration, damage also results from undue stress and live loads placed on sewers.
2. Traffic disruption, disruption to properties, paving damage, shoring requirements, excavation dewatering, noise, flow control and restoration
3. Laterals are lined if infiltration, exfiltration or root intrusion is a problem.
4. Excavation and replacement
5. Chemical grouting
6. True
7. False
8. C
9. B
10. E
11. C
12. A

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Office of Water Washington, D.C.
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Collection Systems O&M Fact Sheet
Trenchless Sewer Rehabilitation

DESCRIPTION

As the infrastructure in the United States ages, increasing importance is being placed on rehabilitating the nation's wastewater treatment collection systems. Cracks, settling, tree root intrusion, and other disturbances that develop over time deteriorate pipe lines and other conveyance structures that comprise wastewater collection systems. These deteriorating conditions can increase the amount of inflow and infiltration (I/I) entering the system, especially during periods of wet weather. Increased I/I levels create an additional hydraulic load on the system and thereby decrease its overall capacity. In addition to I/I flow, storm water may enter the wastewater collection system through illegal connections such as down spouts and sump pumps. If the combination of wastewater, infiltration, and illegal storm water connections entering the wastewater treatment plant exceeds the capacity of the system at any point, untreated wastewater may be released into the receiving water. This bypass of untreated wastewater, known as a Sanitary Sewer Overflow (SSO), may adversely affect human health as well as impair the usage and degrade the water quality of the receiving water.

Under the traditional method of sewer relief, a replacement or additional parallel sewer line is constructed by digging along the entire length of the existing pipeline. While these traditional methods of sewer rehabilitation require unearthing and replacing the deficient pipe (the dig-and-replace method), trenchless methods of rehabilitation use the existing pipe as a host for a new pipe or liner. Trenchless sewer rehabilitation techniques offer a method of correcting pipe deficiencies that requires less restoration and causes less disturbance and environmental degradation than the traditional dig-and-replace method. Trenchless sewer rehabilitation methods include:

- Pipe Bursting, or In-Line Expansion;
- Sliplining;
- Cured-In-Place Pipe; and
- Modified Cross Section Liner.

These alternative techniques must be fully understood before they are applied. These four sewer rehabilitation methods are described further in the following sections.

Pipe Bursting or In-Line Expansion

Pipe bursting, or in-line expansion, is a method by which the existing pipe is forced outward and opened by a bursting tool. The Pipebursting™ method, patented by the British Gas Company in 1980, was successfully applied by the gas pipelines industry before its applicability was identified by other underground utility agencies. Over the last two decades, other methods of in-line expansion have been patented as well. During in-line expansion, the existing pipe is used as a guide for inserting the expansion head (part of the bursting tool). The expansion head, typically pulled by a cable rod and winch, increases the area available for the new pipe by pushing the existing pipe radially outward until it cracks. The bursting device pulls the new pipeline behind itself. The pipe bursting process is illustrated in Figure 1. Various types of expansion heads, categorized as static or dynamic, can be used on the bursting tool to expand the existing pipeline. Static heads, which have no

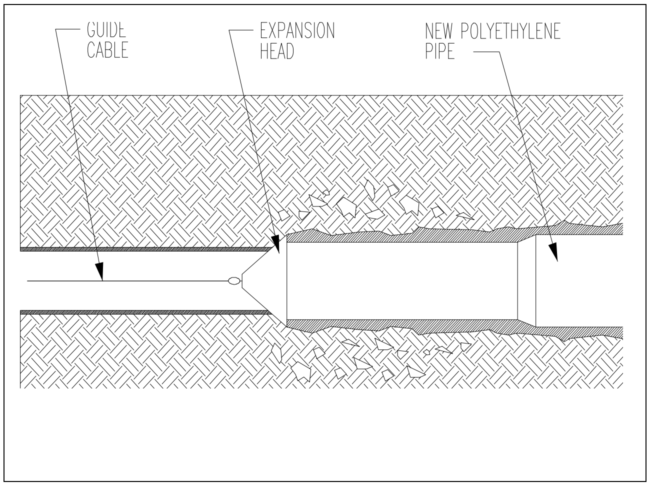

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FIGURE 1 THE PIPE BURSTING PROCESS

moving internal parts, expand the existing pipe only through the pulling action of the bursting tool. Unlike static heads, dynamic heads provide additional pneumatic or hydraulic forces at the point of impact. Pneumatic heads pulsate internal air pressure within the bursting tool, while hydraulic heads expand and collapse the head. While the dynamic head pulsates or expands and contracts, the bursting device is pulled through the existing pipeline and breaks up the existing pipe, replacing it with the new pipe directly behind it. Dynamic heads are often required to penetrate difficult pipe materials and soils. However, because dynamic heads can cause movement of the surrounding soils-resulting in additional pressure and ground settlement-static heads are preferred where pipe and soil conditions permit.

During the pipe bursting process, the rehabilitated pipe segment must be taken out of service by re-routing flows around it. After the pipe bursting is completed, laterals are re-connected, typically with robotic cutting devices.

Sliplining

Sliplining is a well-established method of trenchless rehabilitation. During the sliplining process, a new liner of smaller diameter is placed inside the existing pipe. The annulur space, or area between the existing pipe and the new pipe, is typically grouted to prevent leaks and to provide structural integrity. If the annulus between the sections is not grouted, the liner is not considered a structural liner. Continuous grouting of the annular space provides a seal. Grouting only the end-of-pipe sections can cause failures and leaks.

In most sliplining applications, manholes cannot function as proper access points to perform the rehabilitation. In these situations, an insertion pit must be dug for each pipeline segment. Because of this requirement, in most applications, sliplining is not a completely trenchless technique. However, the excavation required is considerably less than that for the traditional dig-and-replace method. System and site conditions will dictate the amount of excavation spared.

Methods of sliplining include continuous, segmental and spiral wound. All three methods require laterals to be re-connected by excavation or by a remote-cutter. In continuous sliplining, the new pipe, joined to form a continuous segment, is inserted into the host pipe at strategic locations. The installation access point, such as a manhole or insertion pit, must be able to handle the bending of the continuous pipe section.

Installation by the segmental method involves assembling pipe segments at the access point. Sliplining by the segment method can be accomplished without rerouting the existing flow. In many applications, the existing flow reduces frictional resistance and thereby aids in the installation process. Spiral wound sliplining is performed within a manhole or access point by using interlocking edges on the ends of the pipe segments to connect the segments. The spiral wound pipe is then inserted into the existing pipe as illustrated in Figure 2.

Cured-In-Place Pipe

During the cured-in-place pipe (CIPP) renewal process, a flexible fabric liner, coated with a thermosetting resin, is inserted into the existing pipeline and cured to form a new liner. The liner is typically inserted into the existing pipe through an existing manhole. The fabric tube holds the resin in place until the tube is inserted in the pipe and ready to be cured. Commonly manufactured resins include unsaturated polyester, vinyl ester, and

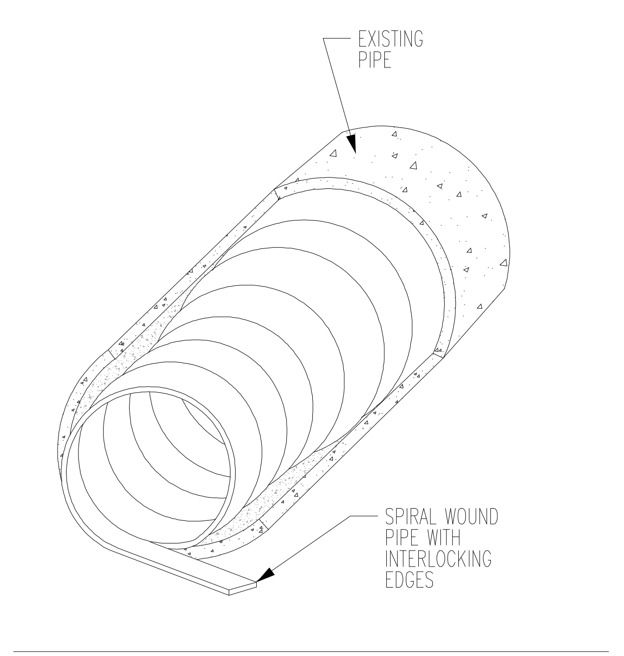

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FIGURE 2. SPIRAL WOUND SLIPLINING PROCESS

epoxy, with each having distinct chemical resistance to domestic wastewater.

The CIPP method can be applied to rehabilitate pipe lines with defects such as cracks, offset joints, and structurally deficient segments. The thermosetting resin material bonds with the existing pipe materials to form a tighter seal than most other trenchless techniques. The two primary methods of installing CIPP are winch-in-place and invert-in-place. These methods are used during installation to feed the tube through the pipe. The winch-in-place method uses a winch to pull the tube through the existing pipeline. After being pulled through the pipeline, the tube is inflated to push the liner against the existing pipe walls. The more typically applied inversion-in-place method uses gravity and either water or air pressure to force the tube through the pipe and invert it, or turn the tube inside out. This process of inversion presses the resin- coated tube against the walls of the existing pipe. During both the winch-in-place and inversion-in-place methods, heat is then circulated through the tube to cure the resin to form a strong bond between the tube and the existing pipe. A typical CIPP process by the water-inversion method is illustrated is Figure 3.

Under both CIPP methods, as the liner expands to fit the new pipe, dimples occur in the line where the laterals exist. Dimples in the line can be found by TV inspection or robotic equipment. In some applications, a Tee is placed at the junction before rehabilitation begins. Tee's enable junctions to be easily identified and modified after the pipeline has been re-lined. Laterals are typically reinstated with robotic cutting devices, or, for large-diameter pipes, by manually cutting the liner.

Modified Cross Section Lining

The modified cross section lining methods include deformed and reformed methods, swagelining™, and rolldown. These methods either modify the pipe's cross sectional profile or reduce its cross-sectional area so that the liner can be extruded through the existing pipe. The liner is subsequently expanded to conform to the existing pipe's size.

During deformed and reformed pipeline renewal, a new flexible pipe is deformed in shape and inserted into the host pipe. While the method of deforming the flexible pipe varies by manufacturer, with many processes referred to as fold and form methods, a typical approach is to fold the new liner into a "U" shape, reducing the pipe's diameter by about 30 percent. After the liner is pulled through the existing line, the liner is heated and pressurized to conform to the original pipe shape. A typical deformed and reformed cross-section is illustrated in Figure 4.

Another method of obtaining a close fit between the new lining and existing pipe is to temporarily compress the new liner before it is drawn through the existing pipeline. The swagelining™ and rolldown processes use chemical and mechanical means, respectively, to reduce the cross-sectional area of the new liner.

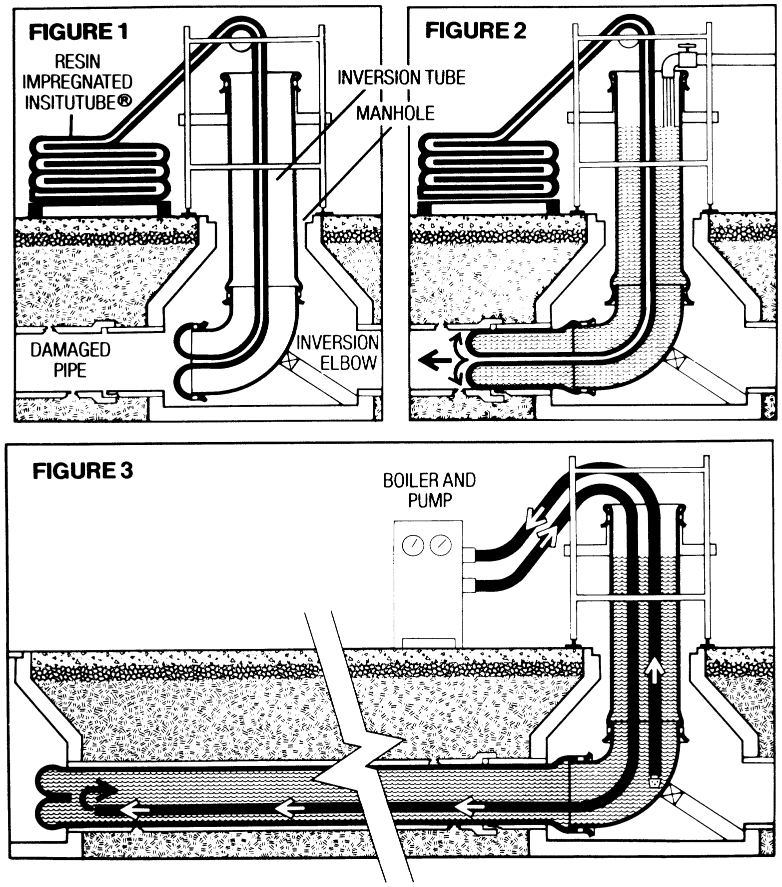
During swagelining™, a typical drawdown process, the new liner is heated and subsequently passed through a reducing die. A chemical reaction between the die and liner material temporarily reduces the liner's diameter by 7 percent to 15

How Insituform® is installed

Figure 1. A special needled felt reconstruction tube, Insitutube®, coated on the outside, is custom engineered and manufactured to fit the damaged pipe exactly. It is impregnated with a liquid thermosetting resin and lowered into a manhole through an inversion tube. One end of the Insitutube is firmly attached to the lower end of the inversion tube elbow.

Figure 2. The inversion tube is then filled with water. The weight of the water pushes the Insitutube into the damaged pipe and turns it inside out, while pressing the resin impregnated side firmly against the inside walls of the old pipe. The smooth coated side of the Insitutube becomes the new interior surface of the pipe.

Figure 3. After the Insitutube is inverted through the old pipe to the desired length, the water is circulated through a boiler. The hot water causes the thermosetting resin to cure within a few hours, changing the pliable Insitutube into a hard, structurally sound, pipe-within-a-pipe, Insitupipe™. It has no joints or seams and is usually stronger than the pipe it replaced. The ends are cut off and the inversion tube and scaffolding are removed. Normally, there are no messy excavation repairs to be made since most work is done without digging or disruption.



Source: Iseley and Najafi, 1995 (from Insituform®)

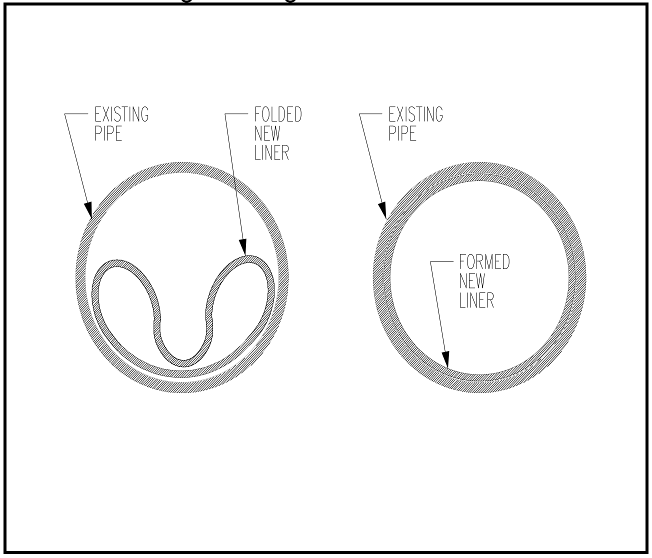
FIGURE 3 A TYPICAL CURED-IN-PLACE PIPE INSTALLATION PROCEDURE

percent and allows the liner to be pulled through the existing pipe. As the new liner cools, it expands to its original diameter. The rolldown process uses a series of rollers to reduce the pipe liner's diameter. As in deform-and-reform methods, heat and pressure are applied to the expand the liner to its original pipe diameter after it has been pulled through the existing pipe.

Unlike CIPP, modified cross section methods do not make use of resins to secure the liner in-place. Lacking resin-coated lining, these methods do not have the curing time requirement of CIPP. A tight fit is obtained when the folded pipe expands to the host pipe's inside diameter under applied heat and pressure. As with the CIPP method, dimples are formed at lateral junctions and similar methods of reconnecting the laterals can be employed. Materials typically used for modified cross section linings include Polyvinyl Chloride (PVC) and High Density Polyethylene (HDPE).

Trenchless sewer rehabilitation methods are now routinely applied to wastewater collection system improvement projects in the United States and many other countries. Trenchless sewer rehabilitation has been successfully applied by both large municipalities such as New York, NY; Los Angeles, CA; Boston, MA; Miami, FL; and Houston, TX; and smaller municipalities such as Baton Rouge, LA; Madison, WI; and Amarillo, TX. Kramer and Thomson (1997) estimate that the market value for sewer and pressure pipe rehabilitation projects will be $5 billion dollars world-wide in the year 2000.

In many municipalities, sewer rehabilitation projects are an essential part of operation and



Source: Created by Parsons Engineering Science, Inc., 1999.

FIGURE 4 DEFORMED AND REFORMED LINERS

maintenance (O&M) programs for the collection system. For example, as part of an O&M program focused on pro-active maintenance, Fairfax County, Virginia, has identified two older sewersheds for rehabilitation. All trunk and main lines within each sewershed are television inspected. Results of the TV inspection are used to prioritize cleaning needs and to help determine appropriate rehabilitation measures. Projects within the targeted sewersheds have utilized the CIPP and fold-and-form rehabilitation methods.

In an effort to monitor the effectiveness of the rehabilitation efforts, the department installed permanent and temporary meters in these two sewersheds. Fairfax County's focused approach to maintenance has reduced average flows to the wastewater treatment plant (WWTP) despite several years of above- normal rainfall.

APPLICABILITY

While trenchless techniques may be applied to rehabilitate existing pipelines in a variety of conditions, they are particularly valuable in urban environments where construction impacts are particularly disruptive to businesses, homeowners, and automotive and pedestrian traffic. Other underground utilities and existing infrastructure are an obstacle in the traditional dig and replace method, and trenchless techniques are widely applied where these are present. Most trenchless techniques are applicable to both gravity and pressure pipelines. Many trenchless methods are capable of performing spot repairs as well as manhole to manhole lining.

For most applications, trenchless sewer rehabilitation techniques require less installation time-and therefore less pump-around time- than traditional dig-and-replace methods. Installation time can be critical in deciding between trenchless sewer rehabilitation methods and dig- and-replace methods. For example, when considering sewer repair or replacement options for a critical force main crossing the Elbe River in Heidenau, Germany, city officials determined that the line could not be out of service for more than 12 days (Saccogna, 1998). As a result of this time constraint, as well as reduced disruption to riverboat traffic, city officials chose to rehabilitate the sewer using the swagelining™ process. The successfully rehabilitated sewer was out of service only eight days.

Trenchless sewer rehabilitation can be performed to increase the hydraulic capacity of the collection system. While pipe bursting typically yields the largest increase in hydraulic capacity, rehabilitation by other trenchless methods may also increase hydraulic capacity, by reducing friction. A hydraulic analysis of the pre- and post-rehabilitation conditions can be performed to evaluate the impact on collection system capacity. In general, the hydraulic analysis is performed by municipal engineers and/or consultants who prepare specifications for contractors.

Each of the trenchless rehabilitation methods described has been used for various applications over a range of pipe sizes and lengths. A comparison of trenchless techniques is shown in Table 1.

ADVANTAGES AND DISADVANTAGES

By reducing I/I levels in the collection system, trenchless rehabilitation projects can assist communities in complying with the EPA's Clean Water Act and thereby protect the aquatic integrity of receiving water-bodies from potentially high

TABLE 1 A COMPARISON OF VARIOUS SEWER REHABILITATION TECHNIQUES

Method:		Diameter Range (mm)	Maximum Installation (m)	Liner Material
In-Line Expansion	Pipe Bursting	100-600 (4-24 in.)	230 (750 ft.)	PE, PP, PVC, GRP
Sliplining	Segmental	100 - 4000 (4-158 in.)	300 (1,000 ft.)	PE, PP, PVC, GRP (-EP & -UP)
	Continuous	100 -1600 (4-63 in.)	300 (1,000 ft.)	PE, PP, PE/EPDM, PVC
	Spiral Wound	150 -2500 (6-100 in.)	300 (1,000 ft.)	PE, PVC, PP, PVDF
Cured-In-Place Product Linings	Inverted-In-Place	100-2700 (4-108 in.)	900 (3,000 ft.)	Theromoset Resin/Fabric Composite
	Winched-In-Place	100 -1400 (4-54 in.)	150 (500 ft.)	Theromoset Resin/Fabric Composite
	Spray-on-Linings	76-4500 (3-180 in.)	150 (500 ft.)	Epoxy Resins/Cement Mortar
Modified Cross-Section Methods	Fold and Form	100-400 (4-15 in.)	210 (700 ft.)	PVC (thermoplastics)
	Deformed/Reformed	100-400 (4-15 in.)	800 (2,500 ft.)	HDPE (thermoplastics)
	Drawdown	62-600 (3-24 in.)	300 (1,000 ft.)	HDPE, MDPE
	Rolldown	62-600 (3-24 in.)	300 (1,000 ft.)	HDPE, MDPE
	Thin-walled lining	500-1,100 (20-46 in.)	960 (3,000 ft.)	HDPE
Internal Point Repair	Robotic Repair	200-760 (8-30 in.)	N/A	Exopy Resins Cement Mortar
	Grouting/Sealing & Spray-on	N/A	N/A	Chemical Grouting
	Link Seal	100-600 (4-24 in.)	N/A	Special Sleeves
	Point CIPP	100-600 (4-24 in.)	15 (50 ft.)	Fiberglass/Polyester, etc.

Note: Spiral wound slipling, robotic repair, and point CIPP can only be used only with gravity pipeline. All other methods can be used with both gravity and pressure pipeline.

EPDM = Ethylene Polypelene Diene Monomer
GRP = Glassfiber Reinforced Polyester
HDPE = High Density Polyethylene
MDPE= Medium Density Polyethylene
PE = Polyethylene
PP = Polypropylene
PVC = Poly Vinyl Chloride
PVDF = Poly Vinylidene Chloride

Source: Iseley and Najafi (1995)

pollutant concentrations by reducing SSOs. In addition to potential improvements in receiving water-bodies, trenchless sewer rehabilitation requires substantially less construction work than traditional dig-and-replace methods. In wetland areas and areas with established vegetation, construction influences can be especially harmful to the plant and aquatic habitat. Underground utility construction can disrupt citizens living and working in areas near the construction zone. Trenchless sewer rehabilitation, with the potential to reduce surface disturbance over traditional dig- and-replace methods, can reduce the number of traffic and pedestrian detours, spare tree removal, decrease construction noise, and reduce air pollution from construction equipment. In addition to these benefits, reducing the amount of underground construction labor and surface construction zone area confines work zones to a limited number of access points, reducing the area where safety concerns must be identified and secured. Rehabilitation techniques should be selected based on site constraints, system characteristics, and project objectives. A comparison of economic, cultural and social costs of sewer rehabilitation with those of traditional dig-and-replace methods can help determine whether or not a trenchless sewer rehabilitation is suitable and economically feasible for a particular site. Because some digging may be required for point repairs, construction limitations should be evaluated when deciding whether trenchless sewer rehabilitation techniques can be applied. If there are major changes in cross section between manholes or if the existing alignment, slope, or pipe bedding material must be changed, each line must be rehabilitated as an independent segment, necessitating even more digging. Specific limitations of each trenchless rehabilitation method are listed in Table 2. As seen, the sliplining, deform-and- reform methods, and CIPP methods will reduce the pipe diameter tending to decrease the hydraulic capacity of the sewer. The rehabilitated pipeline, however, may be less rough than the original. The roughness coefficient depending on the liner material. New high performance plastic materials tend to reduce pipe roughness against aged concrete materials. Additionally, the hydraulic capacity may be modified during rehabilitation as groundwater intrusion is inadvertently redirected to unlined side sewers. An evaluation may be performed to determine whether the change in pipe friction and

TABLE 2 LIMITATIONS OF TRENCHLESS SEWER REHABILITATION

Method	Limitations
Pipe Bursting	Bypass or diversion of flow required Insertion pit required Percussive action can cause significant ground movement May not be suitable for all materials
Sliplining	Insertion pit required Reduces pipe diameter Not well suited for small diameter pipes
CIPP	Bypass or diversion of flow required Curing can be difficult for long pipe segments Must allow adequate curing time Defective installation may be difficult to rectify Resin may clump together on bottom of pipe Reduces pipe diameter
Modified Cross Section	Bypass or diversion of flow required The cross section may shrink or unfold after expansion Reduces pipe diameter Infiltration may occur between liner and host pipe unless sealed Liner may not provide adequate structural support

groundwater redirection will offset the decrease in pipe diameter and meet project objectives for an increase in peak flow and/or reduction in SSOs. Most trenchless rehabilitation applications require laterals to be shut down for a 24 hour period. Coordinating shut-downs with property owners can be a difficult and unpopular task. Unforseen conditions can increase construction time and increase the risk and responsibility to the client and contractor. For example, during a rehabilitation project in Norfolk, Virginia, pipe bursting had to be coordinated with the relocation of a nearby electrical substation and the rerouting of flow from a sanitary force main found in a manhole where an insertion pit was to be located (Small, Gidley, and Riley, 1997). In addition to these issues, numerous abandoned underground utilities which were not indicated on city or private utility records were encountered during the project. Such underground conditions are found in many other urban environments around the United States. When trenchless rehabilitation is planned, public works projects and utility work by other agencies should be coordinated with sewer rehabilitation projects.

PERFORMANCE

The performance of trenchless techniques in reducing I/I can be determined through flow measurements taken before and after the rehabilitation. Effectiveness is typically calculated by correlating flow measurements with precipitation data to determine the peak rate and volume of I/I entering the collection system. Another method of calculating I/I is to isolate the rehabilitated line and measure flows both before and after the rehabilitation.

The performance of sewer rehabilitation projects in three Northeastern Illinois communities was documented by Goumas (1995). Results of pre- and post-monitoring within these three communities indicate that I/I reductions of 49 percent, 65 percent and 82 percent were achieved. The Washington Suburban Sanitary Commission (WSSC) uses the isolation and measurement method to assess the performance of rehabilitation projects. An analysis of 98 sewer mains rehabilitated between 1989 and 1995 indicates that I/I flow was reduced by 70 percent in the rehabilitated sewers (WSSC, 1998).

The Miami-Dade Water and Sewer Department (MDWASD) is completing one of the country's largest I/I reduction programs. The program, aimed at reducing I/I thoughout the system, utilizes the fold and form, CIPP, pipe bursting, and sliplining rehabilitation techniques in conjunction with point and robotic repairs. MDWASD has already experienced success with this program; an average I/I reduction of 19 percent (20 MGD) has been achieved between January 1995 and May 1998 based on comparing plant flow and billed flow (MDWASD, 1998)

In Fairfax County, VA, between June 1994 and June 1998, wet weather flows were significantly reduced within the two sewer sheds identified in the County’s focused rehabilitation program even though the program addresses only main and trunk sewer lines and does not address I/I from private laterals (Fairfax County, 1998).

These studies should only be used as an indicator of potential I/I removal. Removal rates will vary depending on the material and condition of the pipe, local soil type, groundwater flow, and other site-specific conditions.

COSTS

Cost ranges for trenchless rehabilitation of a typical size sewer main are provided in Table 3. These costs include a standard cleaning of the sewer line (major blockages and point repairs increase the cost) and inspection of the sewer line before and after the sewer is rehabilitated. Sewer rehabilitation by both trenchless and traditional dig- and-replace methods can reduce treatment and O&M costs at the receiving treatment plant by potentially eliminating I/I flows to the plant. In addition to treatment cost savings, energy costs for transporting flows to the treatment plant could also be reduced due to the reduced flow volume.

A cost comparison of trenchless and traditional sewer rehabilitation methods must consider the condition and site characteristics of the existing

TABLE 3 TYPICAL COST RANGE FOR SMALL SEWER MAINS

Technique	Pipe Diameter, mm (in.)	Cost Range, per linear meter (ft.)
Pipe Bursting	203 (8)	\$130-\$260 (\$40-\$80)
Sliplining	457 (21)	\$260-\$550 (\$80-\$170)
CIPP	203 (8)	\$80-\$215 (\$25-\$65)
Modified Cross Section	203 (8)	\$58-\$162 (\$18-\$50)

Sources: Kung'u (1998), Burkhard (1998), Cost in 1998 dollars.
These costs are an indicator of some project costs but each project cost is site-specific.

pipeline. Factors influencing the cost of a trenchless sewer rehabilitation project include:

- the diameter of the pipe;
- the amount of pipe to be rehabilitated;
- specific defects in the pipe (such as joint offsets, root intrusions, severe cracking or other defects);
- the depth of the pipe to be replaced, and changes in grade over the pipe length;
- the locations of access manholes;
- the number of additional access points that need to be excavated;
- the location of other utilities that have to be avoided during construction;
- provisions for flow by-pass;
- the number of service connections that need to be reinstated; and
- the number of directional changes at access manholes.

In general, the less the amount of excavation required for a rehabilitation operation, the more cost-effective trenchless sewer rehabilitation becomes as compared with the traditional dig-and-replace method. In addition to excavation and installation costs, sewer cleaning and inspection are typically required before sewer rehabilitation

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Section 14

Cross Connection Control

Cross-Connection Control

TDEC, Fleming Training Center

Outline

- Basics of Cross-Connection Control
- Hydraulics
- Definitions
- Backflow Preventers
- Applications

TDEC, Fleming Training Center

Basics of Cross-Connection Control

United States Environmental Protection Agency
Cross-Connection Control Manual
www.epa.gov/ogwdw/pdfs/crossconnection/crossconnection.pdf

Tennessee Department of Environment & Conservation
Cross-Connection Control Manual & Design Criteria
www.tn.gov/environment/fleming/docs/crossconnection.pdf

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Authority

- Who has responsibility for the water served to the customer?
- Who has the responsibility to protect the water from cross-connections?
- What can happen if the water supplier does not act responsibly in the area of cross-connection control?
- Where does authority for the cross-connection control program come from?
- What can the water provider do to protect their system from contamination?

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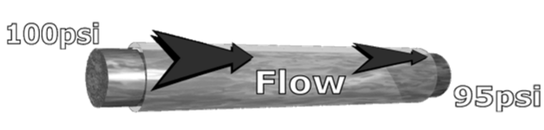
Hydraulics

- Water pressure naturally tends to equalize



- Therefore, water flows from high pressure regions to low pressure regions

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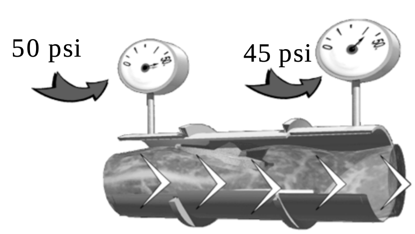
Normal Flow



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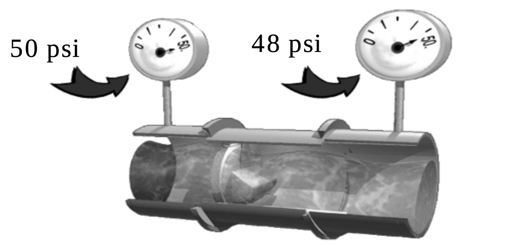
No Flow



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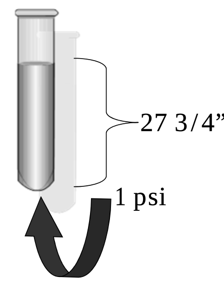
27 ¾” = 2.31 Feet of Head



- 27 3/4” of water generates a pressure of one pound per square inch (psi)

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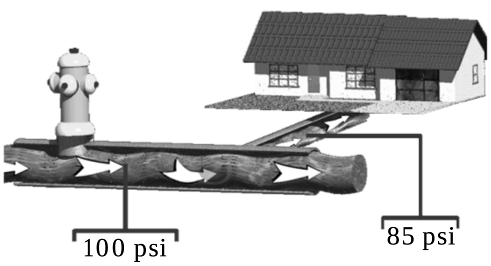
Normal Flow



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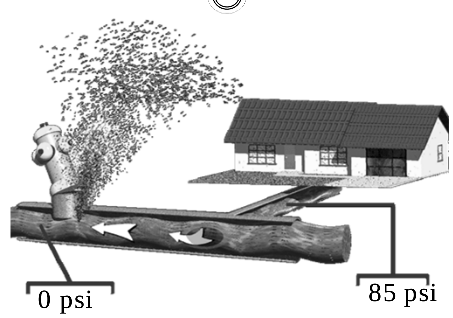
Reverse Flow



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Backflow

- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
  - Backpressure
  - Backsiphonage

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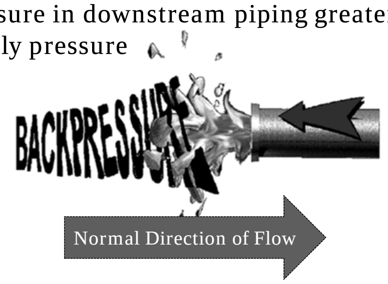
Backpressure

- Pressure in downstream piping greater than supply pressure



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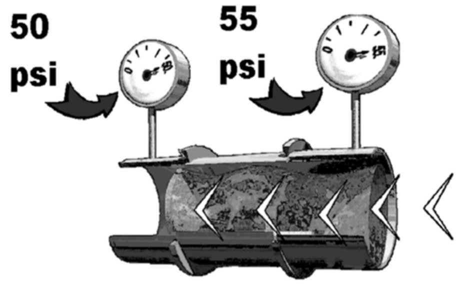
Backpressure



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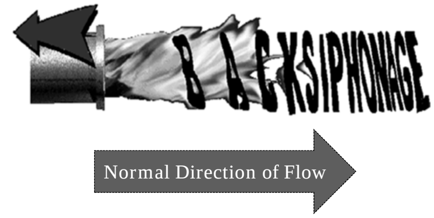
Backsiphonage

- Sub-atmospheric pressure in the water system



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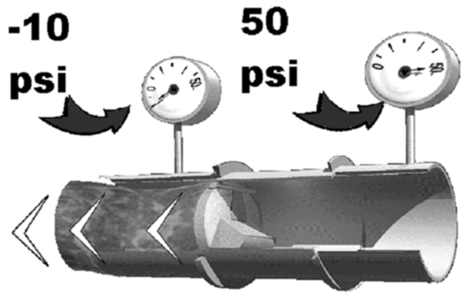
Backsiphonage



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Cross-Connection

- An actual or potential connection between a potable water supply and any non-potable substance or source
- Cross-connection types:
  - Direct
  - Indirect

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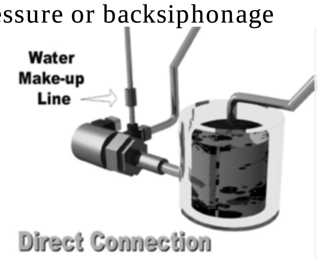
Direct Cross-Connection

- A direct cross-connection is subject to backpressure or backsiphonage



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Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

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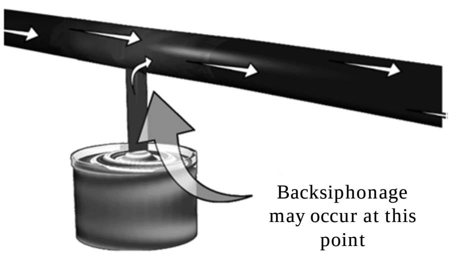
Aspirator Effect



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Degree of Hazard

- Non-Health Hazard
  - Low hazard
  - Will not cause illness or death
  - Pollutant
- Health Hazard
  - High hazard
  - Causes illness or death
  - Contaminant

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The Backflow Incident

For backflow to occur three conditions must be met:

1. There must be a cross-connection. A passage must exist between the potable water system and another source.
2. A hazard must exist in this other source to which the potable water is connected.
3. The hydraulic condition of either backsiphonage or backpressure must occur.

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Five Means of Preventing Backflow

- Air Gap Separation
- Reduced Pressure Principle Assembly
- Double Check Valve Assembly
- Pressure Vacuum Breaker/ Spill-Resistant Vacuum Breaker
- Atmospheric Vacuum Breaker

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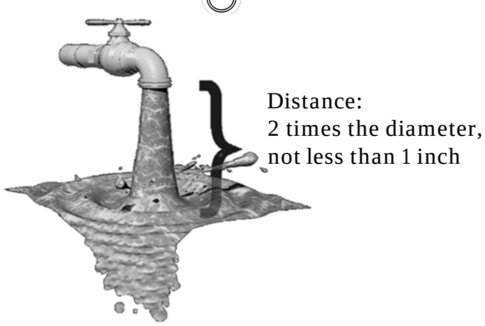
Air Gap



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Approved Air Gap Separation

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	**Air Gap**	**Air Gap**	**Air Gap**
Non – Health Hazard	**Air Gap**	**Air Gap**	**Air Gap**

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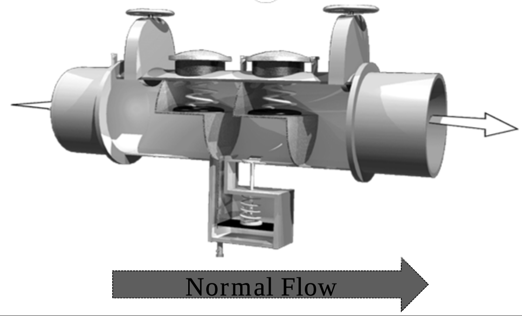
Reduced Pressure Principle Assembly



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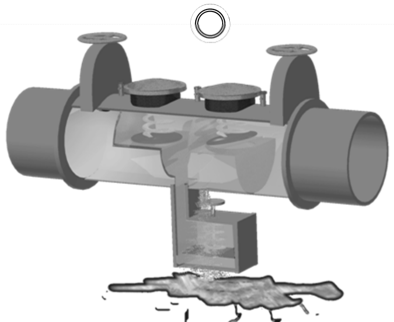
RP



Fouled Second Check with Backpressure

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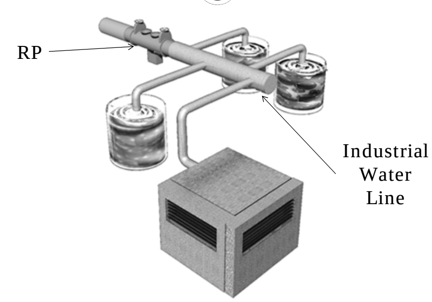
Where To Put an RP



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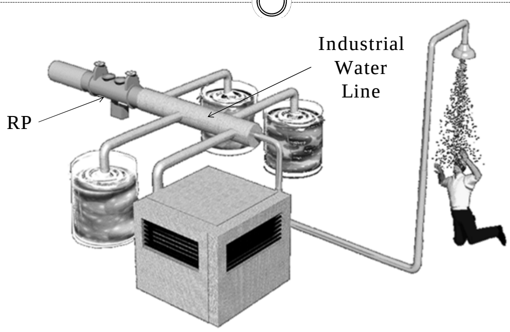
Where To Put an RP – Don't



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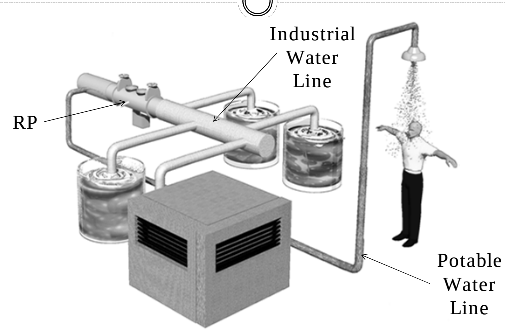
Where To Put an RP – Do



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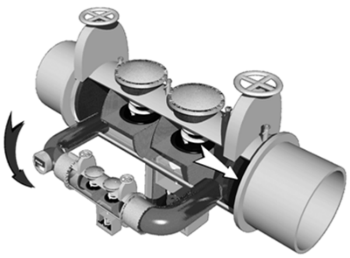
RP Detector Assembly

At least 3 GPM through bypass only

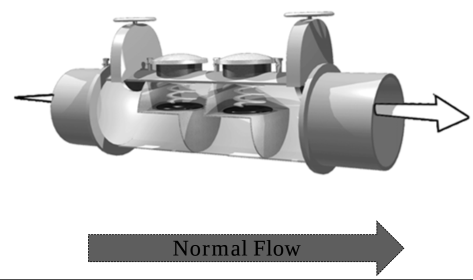


RP

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

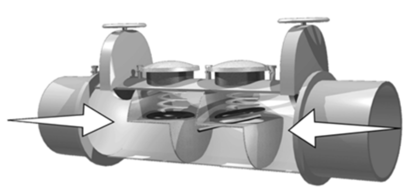
	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	**RP**	**RP**
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	**RP**	**RP**

Double Check Valve Assembly (DC)



Double Check Valve Assembly (DC)

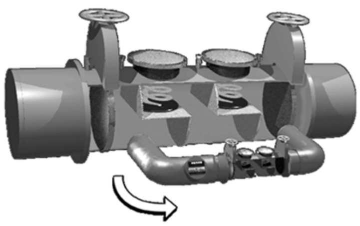
- Second check fouled during backpressure



Double Check Valve Assembly (DC)

- Backsiphonage
- Backpressure
- Pollutant <u>only</u>

DC Detector Assembly



At least 3 GPM through bypass only

	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	**DC**	**DC**

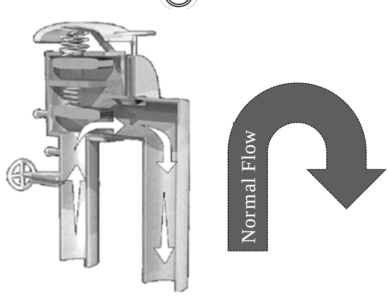
Proper Installation for DC and RP

- USC Recommendations:
  - Minimum 12” above grade
  - Maximum 36” above grade
  - Accessibility for testing and repair
  - Weather/vandalism protection (if needed) with adequate drainage

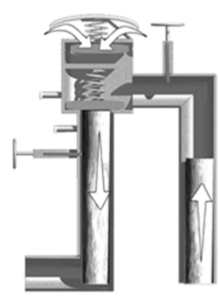
Proper Installation for DC and RP

- Backflow Preventers should only be installed vertically if they have been specifically approved for vertical orientation

Pressure Vacuum Breaker (PVB)

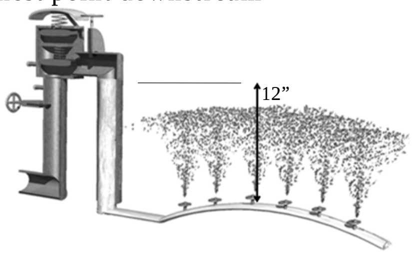


PVB Backsiphonage Condition

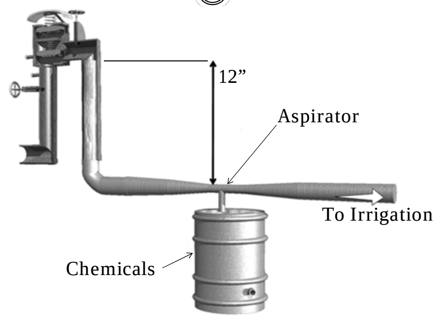


Installation of PVB

- Needs to be installed 12 inches above the highest point downstream

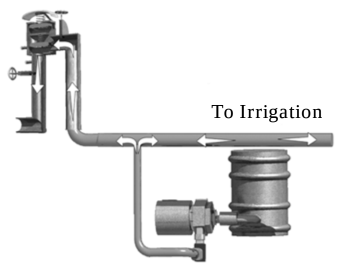


Pressure Vacuum Breaker



Pressure Vacuum Breaker

- Improper installation subject to backpressure

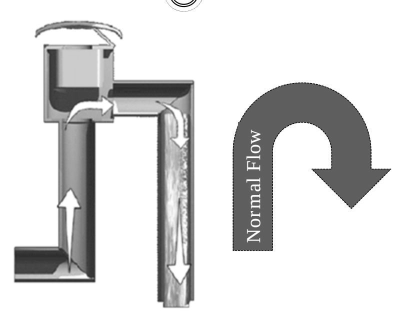


Pressure Vacuum Breaker

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12”

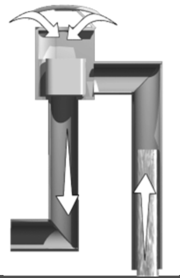
	Indirect		**Direct**
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	**PVB**	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	**PVB**	

Atmospheric Vacuum Breaker (AVB)



Atmospheric Vacuum Breaker (AVB)

- Backsiphonage condition



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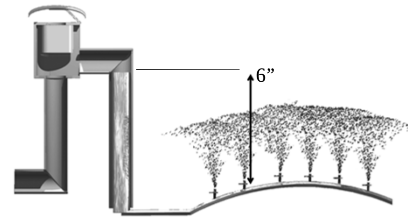
Installation of AVB

- Needs to be installed 6 inches above the highest point downstream



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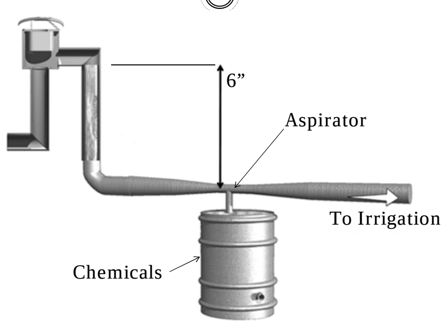
Atmospheric Vacuum Breaker



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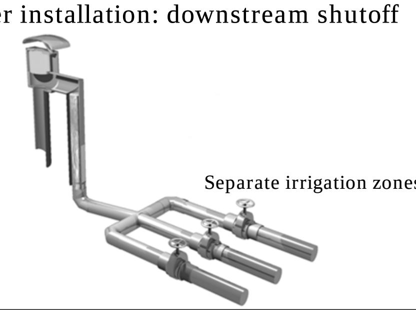
Atmospheric Vacuum Breaker

- Improper installation: downstream shutoff valves



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Atmospheric Vacuum Breaker

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 6”
- Non-Continuous Use

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	PVB	
		AVB	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	PVB	
		AVB	

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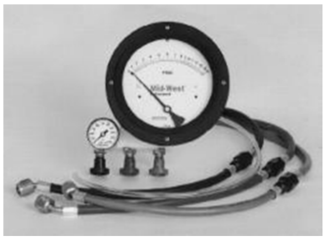
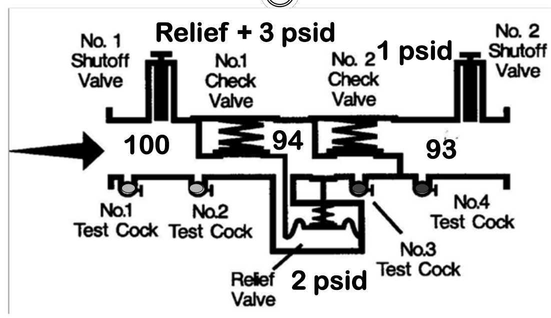
Testing of Assemblies

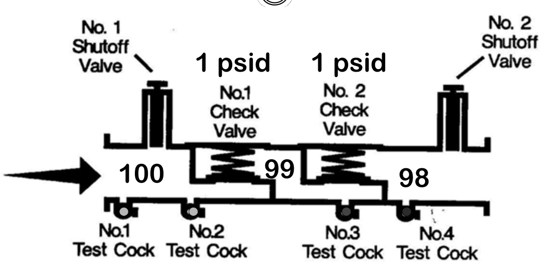
- Annual testing required
- Must be conducted by certified personnel



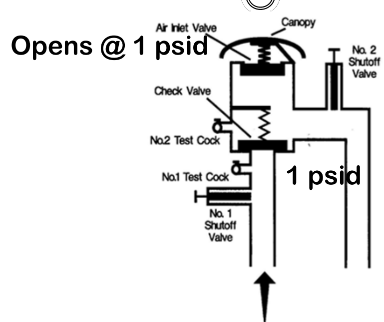
RP

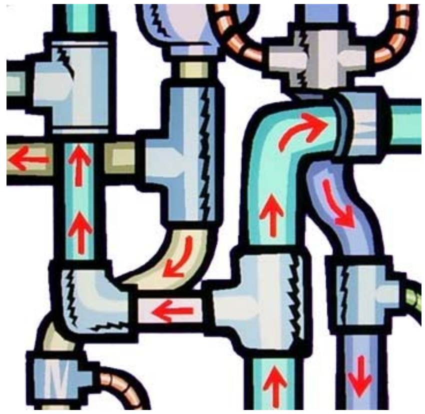


DC



PVB





Vocabulary

Absolute Pressure – The total pressure; gauge pressure plus atmospheric pressure. Absolute pressure is generally measured in pounds per square inch (psi).

Air Gap – The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other device, and the flood-level rim of the receptacle. This is the most effective method for preventing backflow.

Atmospheric Pressure – The pressure exerted by the weight of the atmosphere (14.7 psi at sea level). As the elevation above sea increases, the atmospheric pressure decreases.

Backflow – The reversed flow of contaminated water, other liquids or gases into the distribution system of a potable water supply.

Backflow Prevention Device (Backflow Preventer) – Any device, method or construction used to prevent the backward flow of liquids into a potable distribution system.

Back Pressure (Superior Pressure) – (1) A condition in which the pressure in a nonpotable system is greater than the pressure in the potable distribution system. Superior pressure will cause nonpotable liquids to flow into the distribution system through unprotected cross connections. (2) A condition in which a substance is forced into a water systems because that substance is under higher pressure than the system pressure.

Backsiphonage – (1) Reversed flow of liquid cause by a partial vacuum in the potable distribution system. (2) A condition in which backflow occurs because the pressure in the distribution system is less than atmospheric pressure.

Bypass – Any arrangement of pipes, plumbing or hoses designed to divert the flow around an installed device through which the flow normally passes.

<u>Chemical</u> – A substance obtained by a chemical process or used for producing a chemical reaction.

<u>Containment (Policy)</u> – To confine potential contamination within the facility where it arises by installing a backflow prevention device at the meter or curbstop.

<u>Contamination</u> – The introduction into water of any substance that degrades the quality of the water, making it unfit for its intended use.

<u>Continuous Pressure</u> – A condition in which upstream pressure is applied continuously (more than 12 hours) to a device or fixture. Continuous pressure can cause mechanical parts within a device to freeze.

<u>Cross Connection</u> – (1) Any arrangement of pipes, fittings or devices that connects a nonpotable system to a potable system. (2) Any physical arrangement whereby a public water system is connected, either directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture or other waste or liquid of unknown or unsafe quality.

<u>Cross Connection Control</u> – The use of devices, methods and procedures to prevent contamination of a potable water supply through cross connections.

<u>Degree of Hazard</u> – The danger posed by a particular substance or set of circumstances. Generally, a low degree of hazard is one that does not affect health, but may be aesthetically objectionable. A high degree of hazard is one that could cause serious illness or death.

<u>Direct Connection</u> – Any arrangement of pipes, fixtures or devices connecting a potable water supply directly to a nonpotable source; for example, a boiler feed line.

<u>Distribution System</u> – All pipes, fitting and fixtures used to convey liquid from one point to another.

<u>Double Check-Valve System Assembly</u> – A device consisting of two check valves, test cocks and shutoff valves designed to prevent backflow.

<u>Gauge Pressure</u> – Pounds per square inch (psi) that are registered on a gauge. Gauge pressure measures only the amount of pressure above (or below) atmospheric pressure.

<u>Indirect Connection</u> – Any arrangement of pipes, fixtures or devices that indirectly connects a potable water supply to a nonpotable source; for example, submerged inlet to a tank.

Isolation (policy) – To confine a potential source of contamination to the nonpotable system being served; for example, to install a backflow prevention device on a laboratory faucet.

Liability – Obligated by law.

Negative Pressure – Pressure that is less than atmospheric; negative pressure in a pipe can induce a partial vacuum that can siphon nonpotable liquids into the potable distribution system.

Nonpotable – Any liquid that is not considered safe for human consumption.

Nontoxic – Not poisonous; a substance that will not cause illness or discomfort if consumed.

Physical Disconnection (Separation) – Removal of pipes, fittings or fixtures that connect a potable water supply to a nonpotable system or one of questionable quality.

Plumbing – Any arrangement of pipes, fittings, fixtures or other devices for the purpose of moving liquids from one point to another, generally within a single structure.

Poison – A substance that can kill, injure or impair a living organism.

Pollution – Contamination, generally with man-made waste.

Potable – Water (or other liquids) that are safe for human consumption.

Pressure – The weight (of air, water, etc.) exerted on a surface, generally expressed as pounds per square inch (psi).

Pressure Vacuum Breaker – A device consisting of one or two independently operating, spring-loaded check valves and an independently operating, spring-loaded air-inlet valve designed to prevent backsiphonage.

Reduced-Pressure-Principle or Reduced-Pressure-Zone Device (RP or RPZ) – A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the checks designed to protect against both backpressure and backsiphonage.

Refusal of Service (Shutoff Policy) – A formal policy adopted by a governing board to enable a utility to refuse or discontinue service where a known hazard exists and corrective measures are not undertaken.

Regulating Agency – Any local, state or federal authority given the power to issue rules or regulations having the force of law for the purpose of providing uniformity in details and procedures.

<u>Relief Valve</u> – A device designed to release air from a pipeline, or introduce air into a line if the internal pressure drops below atmospheric pressure.

<u>Submerged Inlet</u> – An arrangement of pipes, fittings or devices that introduces water into a nonpotable system below the flood-level rim of a receptacle.

<u>Superior Pressure</u> – See backpressure.

<u>Test Cock</u> – An appurtenance on a device or valve used for testing the device.

<u>Toxic</u> – Poisonous; a substance capable of causing injury or death.

<u>Vacuum (Partial Vacuum)</u> – A condition induced by negative (sub atmospheric) pressure that causes backsiphonage to occur.

<u>Venturi Principle</u> – As the velocity of water increases, the pressure decreases. The Venturi principle can induce a vacuum in a distribution system.

<u>Waterborne Disease</u> – Any disease that is capable of being transmitted through water.

<u>Water Supplier (Purveyor)</u> – An organization that is engaged in producing and/or distributing potable water for domestic use.

Some Cross-Connections and Potential Hazards

Connected System	Hazard Level
Sewage pumps	High
Boilers	High
Cooling towers	High
Flush valve toilets	High
Garden hose (sil cocks)	Low to high
Auxiliary water supply	Low to high
Aspirators	High
Dishwashers	Moderate
Car wash	Moderate to high
Photographic developers	Moderate to high
Commercial food processors	Low to moderate
Sinks	High
Chlorinators	High
Solar energy systems	Low to high
Sterilizers	High
Sprinkler systems	High
Water systems	Low to high
Swimming pools	Moderate
Plating vats	High
Laboratory glassware or washing equipment	High
Pump primers	Moderate to high
Baptismal founts	Moderate
Access hole flush	High
Agricultural pesticide mixing tanks	High
Irrigation systems	Low to high
Watering troughs	Moderate
Autopsy tables	High

Cross Connection Vocabulary

______1. Air Gap
______2. Atmospheric Vacuum Breaker
______3. Auxiliary Supply
______4. Backflow
______5. Back Pressure
______6. Backsiphonage
______7. Check Valve
______8. Cross Connection
______9. Feed Water
______10. Hose Bibb
______11. Overflow Rim
______12. Pressure Vacuum Breaker
______13. Reduced Pressure Zone Backflow Preventer
______14. RPBP

A. A valve designed to open in the direction of normal flow and close with the reversal of flow.
B. A hydraulic condition, caused by a difference in pressures, in which non-potable water or other fluids flow into a potable water system.
C. Reduced pressure backflow preventer.
D. In plumbing, the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other container, and the overflow rim of that container.
E. A backflow condition in which the pressure in the distribution system is less than atmospheric pressure.
F. A faucet to which a hose may be attached.
G. A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the check valves.
H. Any water source or system, other than potable water supply, that may be available in the building or premises.
I. Water that is added to a commercial or industrial system and subsequently used by the system, such as water that is fed to a boiler to produce steam.
J. A device designed to prevent backsiphonage, consisting of one or two independently operating spring-loaded check valves and an independently operating spring –loaded air-inlet valve.
K. A backflow condition in which a pump, elevated tank, boiler or other means results in a pressure greater than the supply pressure.
L. Any arrangement of pipes, fittings, fixtures or devices that connects a nonpotable water system.
M. The top edge of an open receptacle over which water will flow.
N. A mechanical device consisting of a float check valve and an air-inlet port designed to prevent backsiphonage.

Cross-Connections Review Questions

1. Define a cross-connection.

2. Explain what is meant by backsiphonage and backpressure.

3. List four situations that can cause negative pressure in a potable water supply.
   -
   -
   -
   -

4. List six waterborne diseases that are known to have occurred as a result of cross-connections.
   -
   -
   -
   -
   -
   -

5. What is the most reliable backflow-prevention method?

6. Is a single check valve position protection against backflow? Why or why not?

7. How often should a reduced-pressure-zone backflow preventer be tested?

8. In what position should an atmospheric vacuum breaker be installed relative to a shutoff valve? Why?

9. How does a vacuum breaker prevent backsiphonage?

10. List seven elements that are essential to implement and operate a cross-connection control program successfully?
    -
    -
    -
    -
    -
    -
    -

Vocabulary Answers:

1. D	6. E	11. M
2. N	7. A	12. J
3. H	8. L	13. G
4. B	9. I	14. C
5. K	10. F	

Review Question Answers:

1. A cross-connection is any connection or structural arrangement between a potable water system and a nonpotable system through which backflow can occur.
2. Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In more common terms, there is a partial vacuum on the potable system.
   Backpressure is a condition in which a substance is forced into a water system because that substance is under a higher pressure than system pressure.
3.
   - fire demand
   - a broken water main or exceptionally heavy water use at a lower elevation than the cross-connection
   - a booster pump used on a system
   - undersized piping
4.
   - typhoid fever
   - dysentery and gastroenteritis
   - salmonellosis
   - polio
   - hepatitis
   - brucellosis
5. The most reliable backflow prevention method is an air gap.
6. A single check valve is not considered positive protection against backflow. A check valve can easily be held partially open by debris, corrosion products or scale deposits.
7. Reduced-pressure-zone backflow preventers should be tested at least annually.
8. An atmospheric vacuum breaker must be installed downstream from the last shutoff valve. If it is placed where there will be continuing backpressure, the valve will be forced to remain open, even under backflow conditions.
9. When water stops flowing forward, a check valve drops, closing the water inlet and opening an atmospheric vent. This lets water in the breaker body drain out, breaking the partial vacuum in that part of the system.
10.
    - an adequate cross-connection control ordinance
    - an adequate organization with authority
    - a systematic surveillance program
    - follow-up procedures for compliance
    - provisions for backflow-prevention device approvals, inspection and maintenance
    - public awareness and information programs

Section 15

Safety & Trenching

Safety

Collection Systems

TDEC - Fleming Training Center 1

Safety

- An accident is caused by either an unsafe act or an unsafe environment.
- Personal cleanliness is the best means of protection against infection

TDEC - Fleming Training Center 2

General Duty Clause

- FEDERAL - 29 CFR 1903.1
- Worker Right to Know:
  - EMPLOYERS MUST: Furnish a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm to employees. Employers must comply with occupational safety and health standards promulgated under the Williams-Steiger Occupational Safety and Health Act of 1970.

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Before Leaving the Yard

- Work assignments
- Equipment needs
- Equipment inspection
- Vehicle inspection
  - When backing up a truck, one person should always be at the rear of the truck in view of the driver
  - Mirrors and windows
  - Lights and horn
  - Brakes
  - Tires
  - Trailer hitch/safety chain

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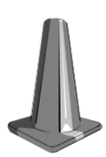
Traffic Safety



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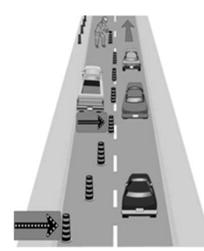
Traffic Control Zones

- Advanced warning area
- Transition area
- Buffer space
- Work area
- Termination area



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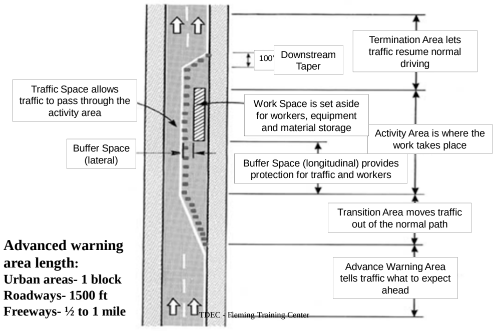
Traffic Control Zones



Advanced warning area length:
Urban areas- 1 block
Roadways- 1500 ft
Freeways- ½ to 1 mile

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Advanced Warning Area

- Must be long enough to give motorists adequate time to respond to particular work area conditions
- Typically ½ mile to one mile for highways
- 1500 feet for most other types of roads
- At least one block for urban streets

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Transition Area

- Not required if no lane or shoulder closure is involved
- Use of tapers
  - Channeling devices or pavement markings placed at an angle to direct traffic
- Traffic is channeled around the work area

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Buffer Space

- Provides margin of safety between transition zone and work area

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Work Area

- Ensure closed to traffic
- Shield by barriers
- Post **Road Construction Next ____ Miles** to inform drivers of the length of work area
- Do Not set up sign until work begins

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Termination Area

- Provides short distance for traffic to clear work area and return to normal traffic lanes
- Closing tapers are optional

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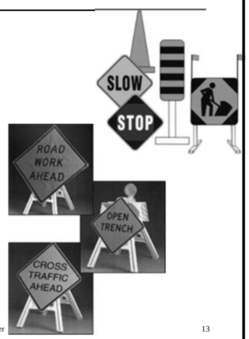
Traffic Signs

- Always use official signs
- Most permanent warning signs are diamond-shaped with black legends on yellow background
- Temporary signs have an orange background
- Best to use picture direction instead of wording
- Place end of construction signs about 500 feet beyond the end of the work site



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Channelizing Devices

- Warn and direct traffic away from workers
- Cones are 18-36 inches high and orange in color
- Drums are 2 orange and 2 white stripes

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Channelizing Devices

- Barricades are alternating orange and white strips marked with reflectors sloping downward in the direction traffic must turn
- Flaggers should wear lime green (or orange) and reflectors at night
- Should be positioned at least 100 feet from the work site always facing the oncoming traffic

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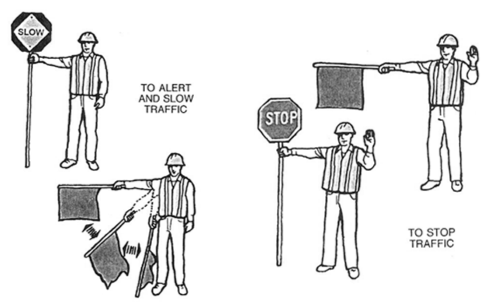
Flaggers



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Confined Space

TDEC - Fleming Training Center 17

Manhole Hazards

- Atmospheric
- Physical injury
- Infection and disease
- Insects and biting animals
- Toxic exposure
- Drowning

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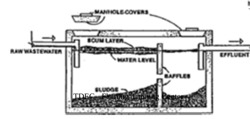
Confined Space Conditions

- Large enough and so configured that an employee can bodily enter and perform assigned work
- Limited or restricted means of entry or exit
- Not designed for continuous employee occupancy

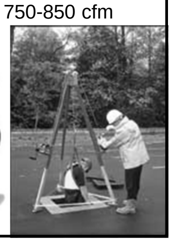
Confined Space Examples

- Storage tanks
- Manholes
- Hoppers
- Vaults
- Septic tanks
- Inside filters
- Basins
- Sewers



Equipment Needed for Confined Spaces

- Safety harness with lifeline, tripod and winch
- Electrochemical sensors
- Ventilation blower with hose
  - Should have a capacity of no less than 750-850 cfm



Equipment Needed for Confined Spaces

- PPE
- Ladder
- Rope
- Breathing Apparatus

Permit Required Confined Space

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf an entrant
- Entrant could be trapped or asphyxiated
- Positions required for entrance into a permit required confined space
  - Supervisor
  - Attendant – at least one person much be outside a permit required space
  - Entrant

Atmospheric Hazards

- Need to have atmosphere monitored!!!
  - Explosive or flammable gas or vapor
    - These can develop in the collection system or sewer plant duel to legal, illegal or accidental sources
  - Toxic or suffocating gases
    - Comes from natural breakdown of organic matter in wastewater or toxic discharges
  - Depletion or elimination of breathable oxygen
    - Oxygen deficient atmosphere
    - Minimum oxygen level is 19.5%

Hydrogen Sulfide – H_2S

- Detected by the smell of rotten eggs
- Loss of ability to detect short exposures
  - Olfactory fatigue
- Not noticeable at high concentrations
- Poisonous, colorless, flammable, explosive and corrosive
- Exposures to .07% to 0.1% will cause acute poisoning and paralyze the respiratory center of the body
- At the above levels, death and/or rapid loss of consciousness occur
- S.G. = 1.19
- Alarm set point = 10 ppm (0.001%)

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Hydrogen Sulfide – H_2S

%	PPM	Hazard
46	460,000	Upper Explosive Limit (UEL)
4.3	43,000	Lower Explosive (LEL)
0.1	1,000	DEAD
0.07	700	Rapid loss of consciousness
0.01	100	IDLH
0.005	50	Eye tissue damage
0.002	20	Eye, nose irritant
0.001	10	Alarm set point

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Methane Gas – CH_4

- Product of anaerobic waste decomposition
- Leaks in natural gas pipelines
  - Odorless unless natural gas supplied through pipeline, has mercaptans added, but soil can strip the odor
- Explosive at a concentration of 5% or 50,000 ppm
- Spaces may contain concentrations above the Lower Explosive Limits (LEL) and still have oxygen above the 19.5% allowable
- Colorless, odorless, tasteless
- Does not decrease oxygen content
- Acts as an asphyxiant
- Coal miners used canaries as early alarms; if bird died, it was time to get out
- S.G.= 0.55
- Alarm set point is 10% LEL = 5000 ppm

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Methane Gas – CH_4

%	PPM	Hazard
85	850,000	Amount in natural gas
65	650,000	Amount in digester gas
15	150,000	Upper Explosive Limit (UEL)
5	50,000	Lower Explosive Limit (LEL)
0.5	5,000	Alarm set point (10% of LEL)

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Carbon Monoxide - CO

- Decreases amount oxygen present
  - Hazardous because it readily binds with hemoglobin in blood, starving the person's body of oxygen
- ALWAYS VENTILATE
- 0.15% (1500 ppm) → DEAD
- Will cause headaches at .02% in two hour period
- Maximum amount that can be tolerated is 0.04% in 60 minute period
- Colorless, odorless, tasteless, flammable and poisonous
- Manufactured fuel gas
- S. G. = 0.97
- Alarm set point at 35 ppm

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Carbon Monoxide - CO

%	PPM	Hazard
74	740,000	Upper Explosive Limit (UEL)
12.5	125,000	Lower Explosive (LEL)
0.2	2,000	Unconscious in 30 minutes
0.15	1,500	IDLH
0.05	500	Sever headache
0.02	200	Headache after 2-3 hours
0.0035	35	8-hour exposure limit
0.0035	35	Alarm set point

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Oxygen – O_2

- ALWAYS ventilate – normal air contains ~ 21%
- Oxygen deficient atmosphere if less than **19.5%**
- Oxygen enriched at greater than **23.5%**
  - Speeds combustion
  - Could be from pure oxygen being used to oxidize hydrogen sulfide
- Leave area if oxygen concentrations approach 22%
- Early warning signs that an operator is not getting enough oxygen:
  - Shortness of breath
  - Chest heaving
  - Change from usual responses

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Oxygen – O_2

%	PPM	Hazard
23.5	235,000	Accelerates combustion
20.9	209,000	Oxygen content of normal air
19.5	195,000	Minimum permissible level
8	8,000	**DEAD** in 6 minutes
6	6,000	Coma in 40 seconds, then **DEAD**

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Oxygen – O_2

- When O_2 levels drop below 16%, a person experiences
  - Rapid fatigue
  - Inability to think clearly
  - Poor coordination
  - Difficulty breathing
  - Ringing in the ears
  - Also, a false sense of well-being may develop

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Oxygen – O_2

- In a confined space, the amount of oxygen in the atmosphere may be reduced by several factors
  - Oxygen consumption
    - During combustion of flammable substances
    - Welding, heating, cutting or even rust formation
  - Oxygen displacement
    - Carbon dioxide can displace oxygen
  - Bacterial action

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Atmospheric Alarm Units

- Continuously sample the atmosphere
- Test atmospheres from manhole areas prior to removing the cover if pick holes available
- Remove manhole covers with non sparking tools
- **Test for oxygen first**
- **Combustible gases second (methane at 5000 ppm)**
  - Atmospheric alarms with a catalytic element are used to test for explosive conditions.

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Atmospheric Alarm Units

- Alarms set to read:
  - Flammable gasses exceeding 10% of the LEL
  - H_2S exceeds 10 ppm and/or
  - O_2 percentage drops below 19.5%
  - CO alarm set point is 35 ppm
- Calibrate unit before using
- Most desirable units: simultaneously sample, analyze and alarm all three atmospheric conditions

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Atmospheric Alarm Units

- Some physical and environmental conditions that could affect the accuracy of gas detection instruments include:
  - Caustic gases
  - Temperature
  - Dirty air
  - Humidity
  - Air velocity
  - Vibration

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Safety Procedures if Explosive Atmosphere Discovered

- Immediately notify supervisor
- Do not remove manhole cover
- Turn off running engines in area
- Route vehicles around area
- Inspect up and downstream of manhole
- Route traffic off the street
- Notify waste and or pretreatment facility
- Cautiously ventilate
- NO SMOKING IN AREA

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Ventilation

- Blowers need to be placed upwind of manhole and at least 10 feet from opening
- Gas driven engine – exhaust must be downwind of manhole
- Air intake should be 2-5 feet above ground service

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Infectious Disease Hazards

- Many diseases may be transmitted by wastewater: hepatitis A, cholera, bacterial dysentery, polio, typhoid, amoebic dysentery
- Ingestion (splashes); inhalation (aerosols); contact (cuts or burns)
- Wash hands frequently
- Avoid touching face
- Never eat, drink or smoke without first washing hands

Best method of protection is person cleanliness!

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Lockout / Tagout

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LOTO General Requirements

- Written program
- Utilize tagout system if energy isolating device not capable of being locked out
- Lockout/tagout hardware provided
- Devices used only for intended purposes
- Tagout shall warn **DO NOT START, DO NOT ENERGIZE, DO NOT OPERATE**
- Only trained employees shall perform lockout/tagout

TDEC - Fleming Training Center 44

Requirements When Lockout of Equipment

- Before beginning work on any pump, the first thing to be done is to lock it out.
  - The person doing the work should have the key
- Notify employees
- Employees notified after completion of work and equipment re-energized

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Recommend Steps for Lockout/Tagout

- Notify employees that device locked and tagged out
- Turn off machine normally
- De-activate energy
- Use appropriate lockout/tagout equipment
- Release any stored energy
- Try to start machine by normal means

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Steps for Restoring Equipment

- Check area for equipment or tools
- Notify all employees in the area
- Verify controls are in neutral
- Remove lockout/tagout devices and re-energize device
- Notify employees maintenance and/or repairs are complete and equipment is operationally

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Training Requirements

- Employer shall train all employees
- All new employees trained
- Recognition of applicable hazardous energy
- Purpose of program
- Procedures
- Consequences
- ANNUAL REQUIREMENT

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Inspections

- Conduct periodic inspection at least annually
- Shall include review between the inspector and each authorized employee
- Recommendation: Frequent walk through of work areas and observation of Maintenance and Operation area

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Required Record Keeping

- Written Lockout/Tagout Program
- Training: Annual and New Employees
- Inspections: Annual including new equipment, inspection of devices, and procedures

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Most Cited Industry Standards By TOSHA

- No written Hazard Communication Program
- Inadequate Hazard Communication Training
- PPE Hazard Assessment not Done
- No Energy Control Program - Lockout/Tagout
- No MSDS on Site
- No one Trained in First Aid
- No Emergency Action Plan
- Metal Parts of Cord and Plug Equipment Not Grounded
- Unlabeled Containers of Hazardous Chemicals

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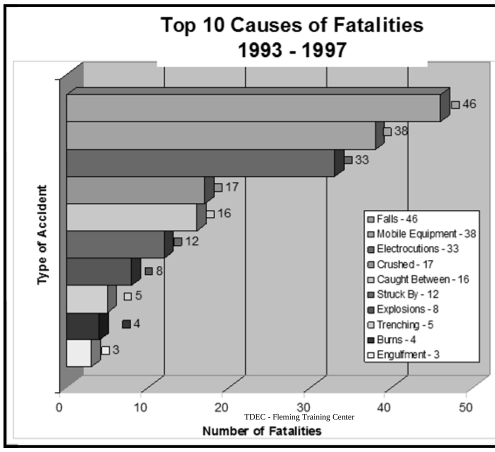

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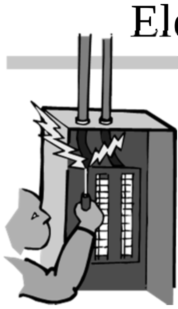
Electrical Safety



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OSHA Says

- Any electrical installations shall be done by a professionally trained electrician.
- Any employee who is in a work area where there is a danger of electric shock shall be trained.
- Employees working on electrical machinery shall be trained in lockout/tagout procedures

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Fire Protection

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Fire Protection Equipment

- Fire extinguishers shall be located where they are readily accessible.
- Shall be fully charged and operable at all times.
  - Charged after each use.
- All fire fighting equipment is to be inspected at least annually.
- Portable fire extinguishers inspected at least monthly and records kept.
- Hydrostatic testing on each extinguisher every five years.
- Fire detection systems tested monthly if batter operated.

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Types of Fire Extinguishers

- Class A
  - Used on combustible materials such as wood, paper or trash
  - Can be water based.
- Class B
  - Used in areas where there is a presence of a flammable or combustible liquid
  - Shall not be water based
  - Example is dry chemical extinguisher
  - An existing system can be used but not refilled.

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Types of Fire Extinguishers

- Class C
  - Use for areas electrical
  - Best is carbon dioxide extinguisher.
  - Using water to extinguish a class C fire risks electrical shock
- Class D
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire.

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Types of Fire Extinguishers

Class	Material	Method
A	Wood, paper	Water
B	Flammable liquids (oil, grease, paint)	Carbon dioxide, foam, dry chemical or Halon
C	Live electricity	Carbon dioxide, dry chemical, Halon
D	Metals	Carbon dioxide

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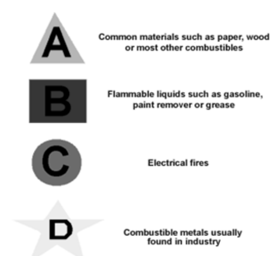
Types of Fire Extinguishers

- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area



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Fire Extinguishers

- To operate a fire extinguisher, remember the word PASS
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

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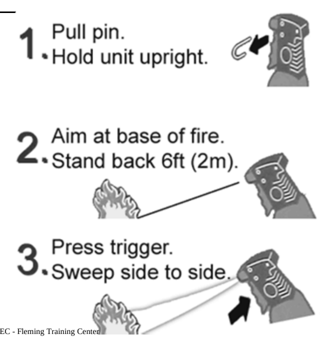
Fire Extinguishers

Combo Extinguisher



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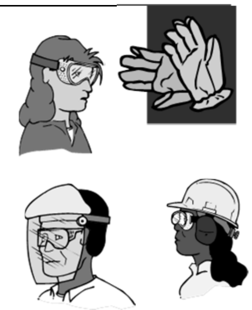
Chemical Safety

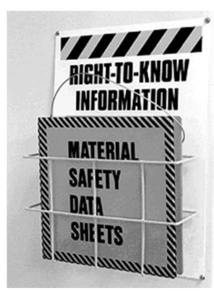
Personal Protective Equipment

- Gloves
- Coveralls / Overalls
- Face Shield / Goggles
- Respirator / SCBA
- Boots
- Ear Plugs / Muffs



Material Safety Data Sheets

- Also called MSDS
- Lists:
  - Common and chemical name
  - Manufacturer info
  - Hazardous ingredients
  - Health hazard data
  - Physical data
  - Fire and explosive data
  - Spill or leak procedures
  - PPE
  - Special precautions



MSDS to SDS

- What is the difference between a MSDS and the new SDS?
- SDSs are in use globally
- The Safety Data Sheets (formerly MSDSs) will now have a specified 16-section format

Minimum Info for SDS

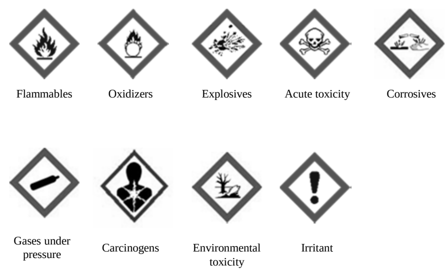
- Product identification
- Hazard Identification
- Composition/info on ingredients
- First-aid measures
- Fire-fighting measures
- Accidental release measures
- Handling and storage
- Exposure controls
- Physical/chemical properties
- Stability & reactivity
- Toxicological information
- Ecological information*
- Disposal considerations*
- Transport information*
- Regulatory information*
- Other information (including date of SDS or last revision)*

***** Non mandatory

MSDS to SDS

- In addition, chemical manufacturers and importers will be required to provide a label that includes a harmonized signal word, pictogram, and hazard statement for each hazard class and category
  - The use of pictograms will enable workers, employers, and chemical users worldwide to understand the most basic chemical information without language barriers

OSHA Pictograms



NFPA

- National Fire Protection Association
- Chemical hazard label
  - Color coded
  - Numerical system
    - Health
    - Flammability
    - Reactivity
  - Special precautions
- Labels are required on all chemicals in the lab

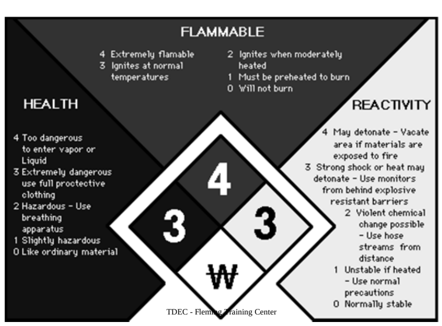
RTK Labels

- "Right to Know"
  - In 1983, OSHA instituted Hazard Communication Standard 1910-1200, a rule that gives employees the right to know the hazards of chemicals to which they may be exposed in the workplace.

Degrees of Hazard

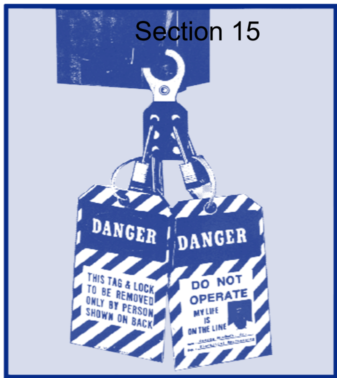
- Each of the colored areas has a number in it regarding the degree of hazard
  - 4 → extreme
  - 3 → serious
  - 2 → moderate
  - 1 → slight
  - 0 → minimal

Chemical Label



Terms

- Lower Explosive Level (LEL) – minimum concentration of flammable gas or vapor in air that supports combustion
- Upper Explosive Limit (UEL) – maximum concentration of flammable gas or vapor in air that will support combustion
- Teratogen – causes structural abnormality following fetal exposure during pregnancy
- Mutagen – capable of altering a cell's genetic makeup



OSHA FACT Sheet

Lockout/Tagout

What is the OSHA standard for control of hazardous energy sources?

The OSHA standard for *The Control of Hazardous Energy (Lockout/Tagout), Title 29 Code of Federal Regulations* (*CFR*) Part 1910.147, addresses the practices and procedures necessary to disable machinery or equipment, thereby preventing the release of hazardous energy while employees perform servicing and maintenance activities. The standard outlines measures for controlling hazardous energies—electrical, mechanical, hydraulic, pneumatic, chemical, thermal, and other energy sources.

In addition, *29 CFR* 1910.333 sets forth requirements to protect employees working on electric circuits and equipment. This section requires workers to use safe work practices, including lockout and tagging procedures. These provisions apply when employees are exposed to electrical hazards while working on, near, or with conductors or systems that use electric energy.

Why is controlling hazardous energy sources important?

Employees servicing or maintaining machines or equipment may be exposed to serious physical harm or death if hazardous energy is not properly controlled. Craft workers, machine operators, and laborers are among the 3 million workers who service equipment and face the greatest risk. Compliance with the lockout/tagout standard prevents an estimated 120 fatalities and 50,000 injuries each year. Workers injured on the job from exposure to hazardous energy lose an average of 24 workdays for recuperation.

How can you protect workers?

The lockout/tagout standard establishes the employer's responsibility to protect employees from hazardous energy sources on machines and equipment during service and maintenance.

The standard gives each employer the flexibility to develop an energy control program suited to the needs of the particular workplace and the types of machines and equipment being maintained or serviced. This is generally done by affixing the appropriate lockout or tagout devices to energy-isolating devices and by deenergizing machines and equipment. The standard outlines the steps required to do this.

What do employees need to know?

Employees need to be trained to ensure that they know, understand, and follow the applicable provisions of the hazardous energy control procedures. The training must cover at least three areas: aspects of the employer's energy control program; elements of the energy control procedure relevant to the employee's duties or assignment; and the various requirements of the OSHA standards related to lockout/tagout.

What must employers do to protect employees?

The standards establish requirements that employers must follow when employees are exposed to hazardous energy while servicing and maintaining equipment and machinery. Some of the most critical requirements from these standards are outlined below:

- Develop, implement, and enforce an energy control program.
- Use lockout devices for equipment that can be locked out. Tagout devices may be used in lieu of lockout devices only if the tagout program provides employee protection equivalent to that provided through a lockout program.
- Ensure that new or overhauled equipment is capable of being locked out.
- Develop, implement, and enforce an effective tagout program if machines or equipment are not capable of being locked out.

Lockout/Tagout

- Develop, document, implement, and enforce energy control procedures. [See the note to *29 CFR* 1910.147(c)(4)(i) for an exception to the documentation requirements.]
- Use only lockout/tagout devices authorized for the particular equipment or machinery and ensure that they are durable, standardized, and substantial.
- Ensure that lockout/tagout devices identify the individual users.
- Establish a policy that permits only the employee who applied a lockout/tagout device to remove it. [See *29 CFR* 1910.147(e)(3) for exception.]
- Inspect energy control procedures at least annually.
- Provide effective training as mandated for all employees covered by the standard.
- Comply with the additional energy control provisions in OSHA standards when machines or equipment must be tested or repositioned, when outside contractors work at the site, in group lockout situations, and during shift or personnel changes.

How can you get more information?

OSHA has various publications, standards, technical assistance, and compliance tools to help you, and offers extensive assistance through its many safety and health programs: workplace consultation, voluntary protection programs, grants, strategic partnerships, state plans, training, and education. Guidance such as OSHA's *Safety and Health Management Program Guidelines* identify elements that are critical to the development of a successful safety and health management system. This and other information are available on OSHA's website at **www.osha.gov**.

- For a free copy of OSHA publications, send a self-addressed mailing label to this address: OSHA Publications Office, P.O. Box 37535, Washington, DC 20013-7535; or send a request to our fax at (202) 693-2498, or call us at (202) 693-1888.
- To file a complaint by phone, report an emergency, or get OSHA advice, assistance, or products, contact your nearest OSHA office under the "U.S. Department of Labor" listing in your phone book, or call us toll-free at **(800) 321-OSHA (6742)**. The teletypewriter (TTY) number is (877) 889-5627.
- To file a complaint online or obtain more information on OSHA federal and state programs, visit OSHA's website.

This is one in a series of informational fact sheets highlighting OSHA programs, policies, or standards. It does not impose any new compliance requirements or carry the force of legal opinion. For compliance requirements of OSHA standards or regulations, refer to *Title 29 of the Code of Federal Regulations.* This information will be made available to sensory-impaired individuals upon request. Voice phone: (202) 693-1999. See also OSHA's website at **www.osha.gov.**

U.S. Department of Labor
Occupational Safety and Health Administration
2002

1

Trenching Safety

2

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Trenching Safety

- Reduction of injury and illness rates.
- Daily exposure to job hazards by thousands of workers.
- Efficiency can be greatly improved.
- OSHA safety standards require:
  - Establishment of a "Safety" program
  - Training be conducted
  - Job hazards be assessed
  - Hazards and precautions be explained

3

OSHA Office of Training and Education

Excavation Hazards

- Cave-ins are the greatest risk

- Other hazards include:
  - Asphyxiation due to lack of oxygen
  - Inhalation of toxic materials
  - Fire
  - Moving machinery near the edge of the excavation can cause a collapse
  - Accidental severing of underground utility lines

4

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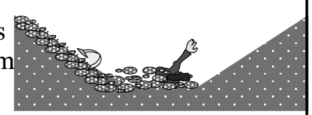
Cave-ins

- Hundreds of workers killed annually from cave-ins
- Thousand of workers injured annually from cave-ins
- Fatality rate for trenching is twice the level for general construction



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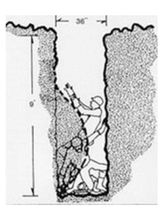
OSHA Office of Training and Education

Injury and Death

- Excavating is one of the most hazardous construction operations
- Most accidents occur in trenches 5-15 feet deep
- There is usually no warning before a cave-in



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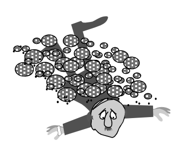
Asphyxiation

- Each time a breath is exhaled the weight of the load restricts inhalation of the next breath.
- Slow suffocation usually follows unless rescue is immediate.



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Cave-ins Result From

- Vibrations
- Adjacent structures
- Freezing and thawing
- Weight of the soil itself
- Addition or removal of water
- Reduction in frictional and cohesive capacities of soil

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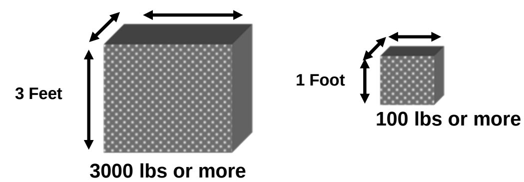
Density and Water Content

- One cubic yard weighs - 3000 lbs or more
- One cubic foot weighs - 100 lbs or more



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How do most deaths occur?

- Instantaneously
- Trenches 5 to 15 feet deep
- With absolutely no warning
- In seemingly safe conditions
- With workers in a bent or lying position

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Before you begin excavation:

- The site must be assessed
- Potential hazards must be determined
- Known hazards reduced or eliminated
- Emergency procedures established
- Periodic inspection intervals determined
- Utility locations must be staked or marked

- Regardless of the equipment used, a sewer trench must be kept as narrow as possible.

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Basic Safety Requirements

- Conduct inspections before each work shift
- Do not travel under elevated loads
- Do not work over unprotected employees
- Wear proper personal protective equipment
- Provide walkways or bridges over trenches

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Basic Safety Requirements

- Provide trench exits within 25 feet of workers in trenches more than four feet deep
  - For every 25 feet of trench there needs to be 1 ladder
- Ensure spoilage is at least 2 ft. from trench edges
- Provide protection for trenches 5 feet or deeper
  - Shores needed
- A registered professional engineer (RPE) must design protective systems for excavations deeper than 20 feet

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Emergency Procedures

- Immediately call 911, or the Emergency Response Team
- Report:
  - Exact Location
  - Number of Victims
  - Nature of Emergency
  - Trench Measurements
  - Special Hazards

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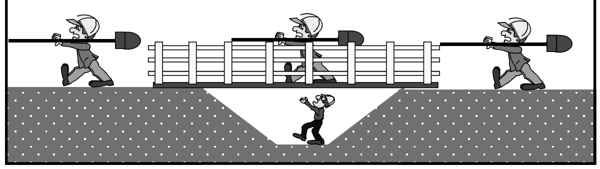
Structural Ramps: Access & Egress

- Used only by people
- Designed by a "competent person"
- Egress required every 25 feet
  - (lateral) ≥ 4ft



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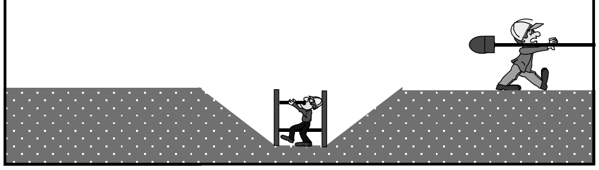
Trench Safety

- Trenches more than 5 feet deep
  - Require shoring
  - Or must have a stabilized slope
- In hazardous soil conditions
  - Trenches under 5 feet need protection



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Hazardous Atmospheres

- Testing and controls
  - Oxygen deficiency
  - Flammable atmospheres
  - testing
- Emergency rescue equipment
  - Availability
  - lifelines

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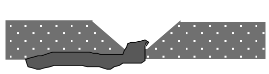
Hazards

- Adequate precautions must be taken when working in accumulated water
- Controlling water and water removal must be monitored by a competent person
- Ditches, dikes or comparable means should be used to prevent surface water from entering excavations



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Weather Factors - Mother Nature

- Don't underestimate the effects weather can have
- Daily (or hourly) site inspections must be made
- Consider protection from:
  - Lightening
  - Flooding
  - Erosion
  - High winds
  - Hot or cold temperatures

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Site Inspections

- Daily inspections must be made by a competent person
  - Excavations
  - Adjacent areas
  - Protective systems
- When evidence is found of a hazardous condition, the exposed employees must be immediately removed from the area

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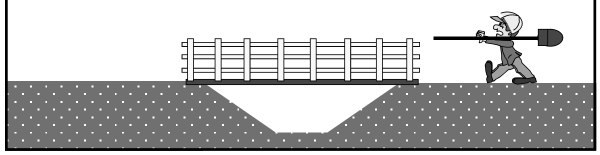
Fall Protection

- Guardrails must be provided for crossing over excavations
- Barriers must be provided for remotely located excavations



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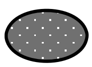
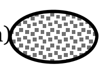
Soil Classification System

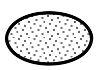
- Type A Soils
  - Clay
  - Silty Clay
  - Sandy Clay
  - Clay Loam



- Type B Soils
  - Granular Cohesionless Soils (Silt Loam)



- Type C Soils
  - Gravel
  - Sand
  - Loamy Sand



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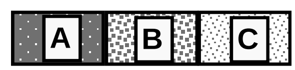
Soil Classification System

- Must be done by a competent person
- Visual test:
  - Check entire worksite
  - Fissured ground
  - Layered soil
  - Disturbed earth
  - Seepage
  - Vibration
  - Poor drainage



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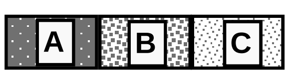
Soil Classification System

- Manual test
  - Plasticity
  - Dry strength
  - Thumb penetration
  - Pocket penetrameter
  - Hand operated shear vane



- Warning:
  - One soil inspection and classification may not be enough.
  - Outside disturbances during excavation may change even the best soil classification.
  - Inspect the soil after any change in conditions.

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Requirements for Protective Systems

- Each employee must be protected from cave-ins by an adequately designed system.
- Exceptions are:
  - Excavation made in stable rock
  - Excavations less than 5 feet
- Protective systems must have the capacity to resist all loads that are expected to be applied to the system

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Materials and Equipment

- Must be free from damage or defects that might impair proper function
- Must be used and maintained in a manner that is consistent with the recommendations of the manufacturer
- Must be examined by a competent person if damage occurs

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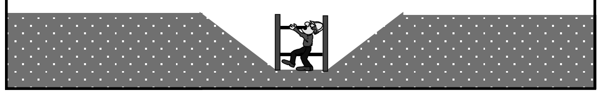
Installation and Removal of Support

- General requirements:
  - Support systems must be securely connected
  - Support systems must be installed and removed in a manner that protects from collapse
  - Support systems must not be subjected to loads exceeding design specifications



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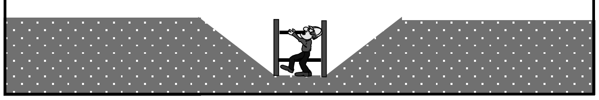
Installation and Removal of Support

- General requirements:
  - Additional precautions must be taken to ensure safety before temporary removal begins
  - Removal must begin at the bottom of the excavation
  - Backfilling must progress together with the removal of support systems from excavations



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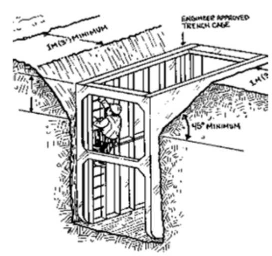
Protect Employees Exposed to Potential Cave-ins

- Slope or bench the sides of the excavation,
- Support the sides of the excavation, or
- Place a shield between the side of the excavation and the work area



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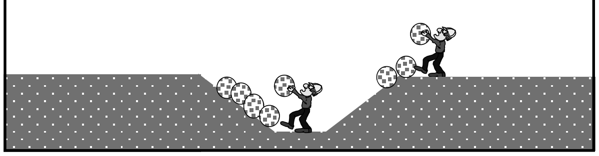
Sloping and Benching Systems

- Employees must not be permitted to work:
  - On the faces of sloped or benched excavations
  - At levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling or sliding material or equipment



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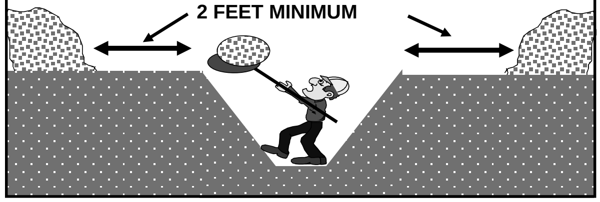
Sloping and Benching Systems

- Temporary spoil piles:



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Spoils

- Don't place spoils within 2 feet from edge of excavation
- Measure from nearest part of the spoil to the excavation edge
- Place spoils so rainwater runs away from the excavation
- Place spoil well away from the excavation

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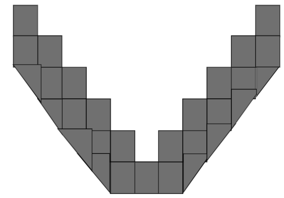
Sloping and Benching Systems

- Benching general requirements
  - Various slope angles are allowed by OSHA
  - Appendix B to 1926 Subpart P must be consulted
  - Evacuate the excavation if walls show signs of distress
  - If soil conditions change, re-inspect



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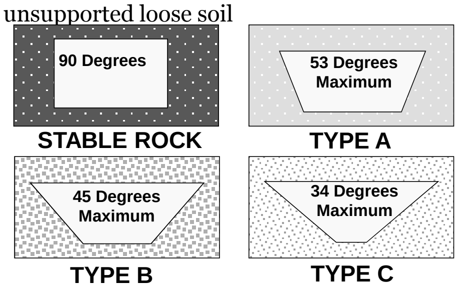
Sloping and Benching Systems

- The angle of repose is the angle of slope of the unsupported loose soil



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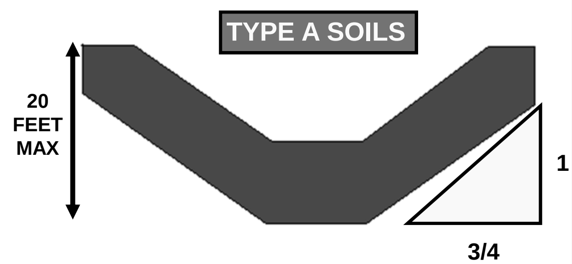
Sloping Example Type A Soils



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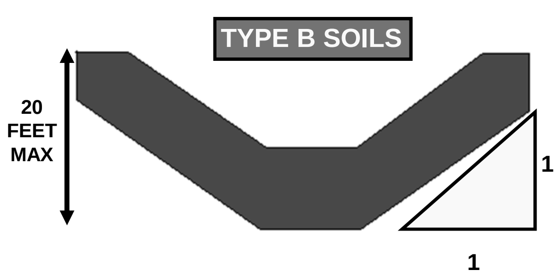
Sloping Example Type B Soils



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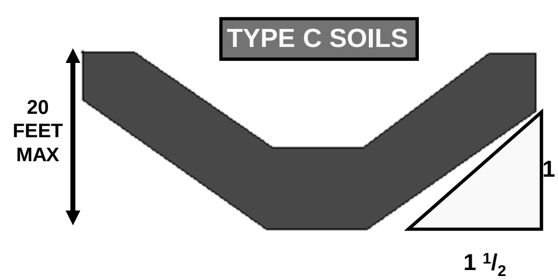
Sloping Example Type C Soils



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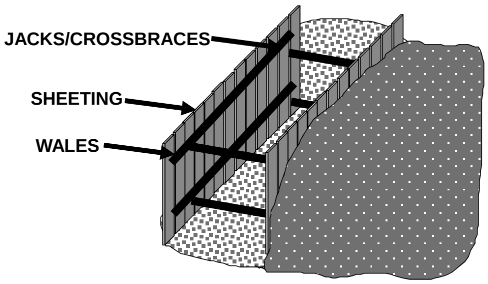
Shoring Systems



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Shoring

- General
  - Provides a framework to work in
  - Uses wales, cross braces and uprights
  - Supports excavation walls
- OSHA tables provide shoring data
  - Must know soil type
  - Must know depth and width of excavation
  - Must be familiar with the OSHA Tables

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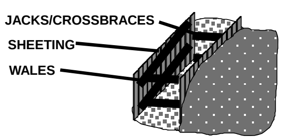
Shoring Systems

- Removal
  - Remove shoring from the bottom up
  - Pull sheeting out from above
  - Backfill immediately after removal of support system



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Hydraulic Trench Support

- Using hydraulic jacks the operator can easily drop the system into the hole
- Once in place, hydraulic pressure is increased to keep the forms in place
- Trench pins are installed in case of hydraulic failure

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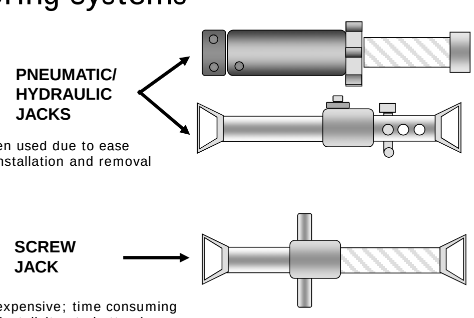
Shoring Systems



Often used due to ease of installation and removal

Inexpensive; time consuming to install (top to bottom).

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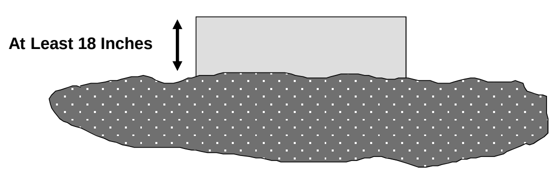
Shield Systems

- General
  - Shield systems must project at least 18 inches above the lowest point where the excavation face begins to slope



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Shield Systems

- General
  - Shield systems must not be subjected to loads exceeding those which the system was designed to withstand
  - Shields must be installed to restrict hazardous movement
  - Employees must be protected from the hazard of cave-ins when entering or exiting the areas protected by shields
  - Employees must not be allowed in shields when shields are being installed, removed, or moved vertically

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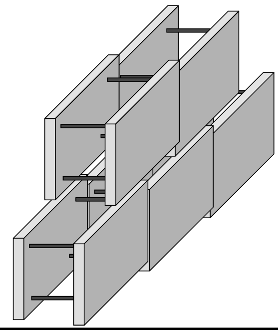
Shield Systems

- Systems may be connected
- Systems may be stacked
- Configuration must be consistent with the recommendations of the manufacturer
- Must be examined by a competent person if damage occurs



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Trench Shield

A trench shield was built around this work area

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Cave-in Hazard

Inadequate protective system

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Hazardous Conditions

- The weight and vibrations of the crane make this a very hazardous condition.
- They should not be working under this crane.

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Materials and Equipment

- Equipment used for protective systems must not have damage or defects that impair function.
- If equipment is damaged, the competent person must examine it to see if it is suitable for continued use.
- If not suitable, remove it from service until a professional engineer approves it for use.

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Protection from Vehicles

- Install barricades
- Hand/mechanical signals
- Stop logs
- Grade soil away from excavation
- Fence or barricade trenches left overnight

Trenching Summary

- Provide stairways, ladders, ramps or other safe means of access in all trenches **4 feet** or deeper
  - These devices must be located within **25 feet** of all workers
  - Ladders used in trenches shall protrude at least **3 feet** above the trench edge
  - Minimum diameter of rungs on a fixed steel ladder is **¾-inch**
  - Minimum clear length of rungs on a fixed steel ladder is **16 inches**

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Trenching Summary

- Trenches **5 feet** deep or greater require a protective system, which can be shielding, shoring or sloping
  - A registered engineer must approve all shielding and shoring
- Trenches **20 feet** deep or greater require that the protective system be designed by a registered professional engineer
- Keep excavated soil (spoils) and other materials at least **2 feet** from trench edges.
- The support or shield system must extend at least **18 inches** above the top of the vertical side.

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OSHA® FactSheet

Trenching and Excavation Safety

Two workers are killed every month in trench collapses. The employer must provide a workplace free of recognized hazards that may cause serious injury or death. The employer must comply with the trenching and excavation requirements of 29 CFR 1926.651 and 1926.652 or comparable OSHA-approved state plan requirements.

An excavation is any man-made cut, cavity, trench, or depression in an earth surface formed by earth removal.

Trench (Trench excavation) means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 meters).

Dangers of Trenching and Excavation

Cave-ins pose the greatest risk and are much more likely than other excavation-related accidents to result in worker fatalities. Other potential hazards include falls, falling loads, hazardous atmospheres, and incidents involving mobile equipment. One cubic yard of soil can weigh as much as a car. An unprotected trench is an early grave. Do not enter an unprotected trench.

Trench Safety Measures

Trenches 5 feet (1.5 meters) deep or greater require a protective system unless the excavation is made entirely in stable rock. If less than 5 feet deep, a competent person may determine that a protective system is not required.

Trenches 20 feet (6.1 meters) deep or greater require that the protective system be designed by a registered professional engineer or be based on tabulated data prepared and/or approved by a registered professional engineer in accordance with 1926.652(b) and (c).

Competent Person

OSHA standards require that employers inspect trenches daily and as conditions change by a competent person before worker entry to ensure elimination of excavation hazards. A competent person is an individual who is capable of identifying existing and predictable hazards or working conditions that are hazardous, unsanitary, or dangerous to workers, soil types and protective systems required, and who is authorized to take prompt corrective measures to eliminate these hazards and conditions.

Access and Egress

OSHA standards require safe access and egress to all excavations, including ladders, steps, ramps, or other safe means of exit for employees working in trench excavations 4 feet (1.22 meters) or deeper. These devices must be located within 25 feet (7.6 meters) of all workers.

General Trenching and Excavation Rules

- Keep heavy equipment away from trench edges.
- Identify other sources that might affect trench stability.
- Keep excavated soil (spoils) and other materials at least 2 feet (0.6 meters) from trench edges.
- Know where underground utilities are located before digging.
- Test for atmospheric hazards such as low oxygen, hazardous fumes and toxic gases when > 4 feet deep.
- Inspect trenches at the start of each shift.
- Inspect trenches following a rainstorm or other water intrusion.
- Do not work under suspended or raised loads and materials.
- Inspect trenches after any occurrence that could have changed conditions in the trench.
- Ensure that personnel wear high visibility or other suitable clothing when exposed to vehicular traffic.

Protective Systems

There are different types of protective systems.

Benching means a method of protecting workers from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels. *Benching cannot be done in Type C soil.*

Sloping involves cutting back the trench wall at an angle inclined away from the excavation.

Shoring requires installing aluminum hydraulic or other types of supports to prevent soil movement and cave-ins.

Shielding protects workers by using trench boxes or other types of supports to prevent soil cave-ins. Designing a protective system can be complex because you must consider many factors: soil classification, depth of cut, water content of soil, changes caused by weather or climate, surcharge loads (e.g., spoil, other materials to be used in the trench) and other operations in the vicinity.

Additional Information

Visit OSHA's Safety and Health Topics web page on trenching and excavation at
www.osha.gov/SLTC/trenchingexcavation/index.html
www.osha.gov/dcsp/statestandard.html

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory-impaired individuals upon request. The voice phone is (202) 693-1999; teletypewriter (TTY) number: (877) 889-5627.

For assistance, contact us. We can help. It's confidential.

Occupational Safety and Health Administration

U.S. Department of Labor
www.osha.gov (800) 321-OSHA (6742)

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TOSHA Standards Requiring Annual Training

Class	Regulation	Who should attend?
Medical & Exposure Records	1910.20(g)(1)	All employees (inform- existence, person responsible, location, right of access
Emergency Action	1910.38(a)(5) 1910.38(b)(4)	All employees – based upon other standards and requirements
Noise	1910.95(k)	All employees exposed to an 8 hour TWA or greater of 85dBA
Emergency Response	1910.120(q)	Employees who respond to spills of hazardous chemicals
Personal Protective Equipment	1910.132(f)	Employees who wear PPE
Permit-Required Confined Space	1910.146(g)	Employees who enter, attend or supervise P.R. confined spaces
Lock-Out/Tag-Out	1910.147(c)(7)	Employees who work on machinery
First Aid	1910.151(b)	At least one employee on each shift, annual as required by other standards
Fire Brigade	1910.156(c)	All fire brigade members (quarterly and annually)
Portable Fire Extinguishers	1910.157(g)	All employees expected to use fire extinguishers
Fork Lift Trucks	1910.178(1)	Fork lift truck operators
Mechanical Power Presses	1910.217(f)(2)	Operators
Asbestos	1910.1001(j)(1)	All employees exposures at or above PEL or excursion limit
Lead	1910.1025(1)	Anyone with a potential for exposure at any level – copy of appendix A&B. If exposed at or above action level, must be trained
Bloodborne Pathogens	1910.1030(g)(2)	Employees who render first aid
Hazard Communication	1910.1200(h) TDL 800-1-9-.07	Employees exposed or potentially exposed to any type of chemicals
Hazardous Chemicals in Laboratories	1910.1450(f)(2)	Employees exposed to chemicals

OSHA QUICK CARD™

Protect Yourself
Trench Safety

- **Do not enter an unprotected trench!**
- Trench collapses cause dozens of fatalities and hundreds of injuries each year.
- Trenches **5** feet deep or greater require a **protective system**.
- Trenches **20** feet deep or greater require that the protective system be **designed by a registered professional engineer**.

Protective Systems for Trenches

- **Sloping** protects workers by cutting back the trench wall at an angle inclined away from the excavation.
- **Shoring** protects workers by installing aluminum hydraulic or other types of supports to prevent soil movement.
- **Shielding** protects workers by using trench boxes or other types of supports to prevent soil cave-ins.

Competent Person

OSHA standards require that trenches be inspected daily and as conditions change by a competent person prior to worker entry to ensure elimination of excavation hazards.

Safety Tips

- Inspect trenches at the start of each shift, following a rainstorm or after any other hazardous event.
- Test for low oxygen, hazardous fumes and toxic gases before entering a trench.
- Keep heavy equipment and excavation spoils at least two feet away from the trench edge.
- Provide stairways, ladders, ramps or other safe means of access in all trenches 4 feet or deeper.

Think Safety!

For more complete information:

OSHA Occupational Safety and Health Administration
U.S. Department of Labor
www.osha.gov (800) 321-OSHA

OSHA 3197-04N-04

Sewer Safety Vocabulary

______1. Aerobic
______2. Ambient
______3. Anaerobic
______4. Competent Person
______5. Confined Space
______6. Confined Space, Non-Permit
______7. Confined Space, Permit-Required
______8. Decibel
______9. Engulfment
______10. Fit Test
______11. IDLH
______12. Mercaptans
______13. Olfactory Fatigue
______14. Oxygen Deficiency
______15. Oxygen Enrichment
______16. Septic
______17. Sewer Gas
______18. Spoil

A. A condition where atmospheric or dissolved molecular oxygen is not present in the aquatic (water) environment.
B. A unit for expressing the relative intensity of sounds on a scale from zero for the average least perceptible sound to about 130 for the average level where sound causes pain to humans. Abbreviated dB.
C. A space which is large enough and so configured that an employee can bodily enter and perform assigned work; has limited or restricted means for entry or exit and it not designed for continuous employee occupancy.
D. Compounds containing sulfur that have an extremely offensive skunk-like odor; also sometimes described as smelling like garlic or onions.
E. The use of a procedure to qualitatively or quantitatively evaluate the fit of a respirator on an individual.
F. An atmosphere containing oxygen at a concentration of less than 19.5% by volume.
G. A condition where atmospheric or dissolved molecular oxygen is present in the aquatic (water) environment.
H. A condition produced by anaerobic bacteria. If severe, the wastewater produces hydrogen sulfide, turns black, gives off foul odors, contains little or no dissolved oxygen and the wastewater has a high oxygen demand.
I. Immediately Dangerous to Life or Health. The atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere.
J. Gas in collection lines (sewers) that result from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.
K. A person capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate the hazards.
L. Excavated material such as soil from the trench of a sewer.

M. The surrounding and effective capture of a person by a liquid or finely divided (flowable) solid substance that can be aspirated to cause death by filling or plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction or crushing.

N. A condition where a person's nose, after exposure to certain odors, is no longer able to detect the odor.

O. A confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.

P. An atmosphere containing oxygen at a concentration of more than 23.5% by volume.

Q. Surrounding. Ambient or surrounding atmosphere.

R. A confined space that has one or more of the following characteristics: contains or has the potential to contain a hazardous atmosphere; contains a material that has the potential for engulfing an entrant; has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section; or contains any other recognized serious safety of health hazard.

Safety Questions

1. How can traffic be warned of your presence in the street?

2. What is the <u>purpose</u> of the advance warning area?

3. List <u>six</u> types of traffic control devices.

4. How can explosive or flammable atmosphere develop in a collection system?

5. What types of hazardous atmospheres should an atmospheric test unit be able to detect in confined spaces?

6. If operators are scheduled to work in a manhole, when should the atmosphere in the manhole be tested?

7. When a blower is used to ventilate a manhole, where should the blower be located?

8. List the safety equipment recommended for use when operators are required to enter a confined space.

9. What are some early signs that an operator working in a manhole or other confined space is not getting enough oxygen?

10. How can collection system operators be protected from injury by the accidental discharge of stored energy?

11. How can collection system operators protect their hearing from loud noises?

12. How would you extinguish a fire?

Answers to Vocabulary and Questions

Vocabulary:

1. G	5. C	9. M	13. N	17. J
2. Q	6. O	10. E	14. F	18. L
3. A	7. R	11. I	15. P	
4. K	8. B	12. D	16. H	

Questions:
1. Traffic can be warned of your presence in a street by signs, flags or flashers and vehicles with rotating flashing lights. Vehicle-mounted traffic guides are also helpful. Flaggers can be used to alert drivers and to direct traffic around a work site.
2. The purpose of the advance warning area is to give drivers enough time to see what is happening ahead and adjust their driving patterns.
3. Types of traffic control devices include: signs, barricades, traffic cones, drums, vertical panels, lighting devices, advance warning arrow boards, flashing vehicle lights, high level warning devices and portable changeable message signs. Flaggers may also be used to control traffic.
4. Explosive or flammable atmospheres can develop at any time in the collection system. Flammable gases or vapors may enter a sewer or manhole from a variety of legal, illegal or accidental sources.
5. An atmospheric test unit should be able to detect flammable and explosive gases, toxic gases and oxygen deficiency.
6. If operators are scheduled to work in a manhole, the atmosphere in the manhole should be tested before anyone enters it, preferably before the cover is even removed, and atmospheric testing should continue for the entire time anyone is working in the manhole.
7. The blower used to ventilate a manhole should be located in an area upwind of the manhole and at least 10 feet from the manhole opening. If the blower has a gas-driven engine, the exhaust must be downwind from the manhole. The air intake to the blower should be 2-5 feet above the ground surface, depending on conditions (higher for dusty conditions).
8. SCBA (self-contained breathing apparatus); safety harness with lifeline, tripod and winch; portable atmospheric alarm unit; ventilation blower with hose; manhole enclosure (if entering a manhole); ladder or tripod with winch; ropes and buckets; hard hats; protective clothing; cones and barricades; firs-aid kit; soap, water, paper towels and a trash bag
9. The early warning signs that an operator is not getting enough oxygen include: labored breathing (shortness of breath), chest heaving and change from usual responses
10. Operators can be protected from injury due to the accidental discharge of stored energy by following prescribed lockout/ tagout procedures.
11. Collection system operators can protect their hearing from loud noises by use of approved earplugs, earmuffs and/or person protective equipment.
12. To extinguish a fire, first identify the material burning (class or category) and then use the appropriate method to put out the fire.